US009281704B2

(12) **United States Patent**
Heo et al.

(10) **Patent No.: US 9,281,704 B2**
(45) **Date of Patent: Mar. 8, 2016**

(54) **METHOD OF CONTROLLING A LOAD CURRENT, LOAD CURRENT CONTROL DEVICE, AND MOBILE DEVICE HAVING THE SAME**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 270 days.

(21) Appl. No.: **13/959,043**

(22) Filed: **Aug. 5, 2013**

(65) **Prior Publication Data**

US 2014/0047248 A1 Feb. 13, 2014

(30) **Foreign Application Priority Data**

Aug. 9, 2012 (KR) 10-2012-0087074

(51) **Int. Cl.**

G06F 1/32 (2006.01)
H02J 7/00 (2006.01)
G06F 1/26 (2006.01)

(52) **U.S. Cl.**

CPC ***H02J 7/0068*** (2013.01); ***G06F 1/26*** (2013.01); ***H02J 7/0063*** (2013.01); *H02J 2007/0067* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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(57) **ABSTRACT**

A method of controlling a load current is provided. By the method, a battery voltage control operation is begun when a battery voltage becomes lower than a first threshold value, whether a gradient of the battery voltage is a positive gradient or a negative gradient is determined at an interval of a reference or, alternatively, predetermined control time, the load current is controlled based on the gradient of the battery voltage at an interval of the reference or, alternatively, predetermined control time, and the battery voltage control operation is finished when the battery voltage becomes higher than a second threshold value.

33 Claims, 17 Drawing Sheets

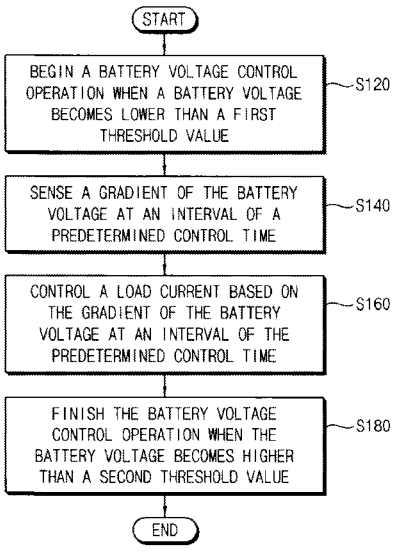


FIG. 1

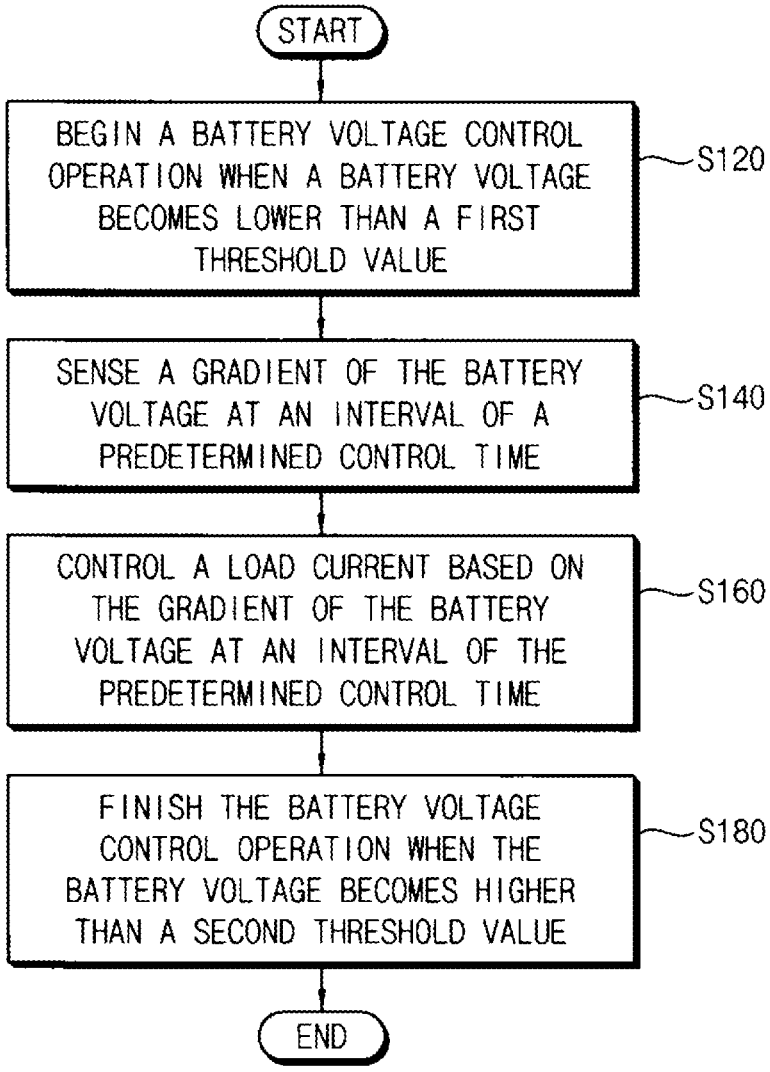

START
BEGIN A BATTERY VOLTAGE CONTROL OPERATION WHEN A BATTERY VOLTAGE BECOMES LOWER THAN A FIRST THRESHOLD VALUE
S120
SENSE A GRADIENT OF THE BATTERY VOLTAGE AT AN INTERVAL OF A PREDETERMINED CONTROL TIME
S140
CONTROL A LOAD CURRENT BASED ON THE GRADIENT OF THE BATTERY VOLTAGE AT AN INTERVAL OF THE PREDETERMINED CONTROL TIME
S160
FINISH THE BATTERY VOLTAGE CONTROL OPERATION WHEN THE BATTERY VOLTAGE BECOMES HIGHER THAN A SECOND THRESHOLD VALUE
S180
END

FIG. 2

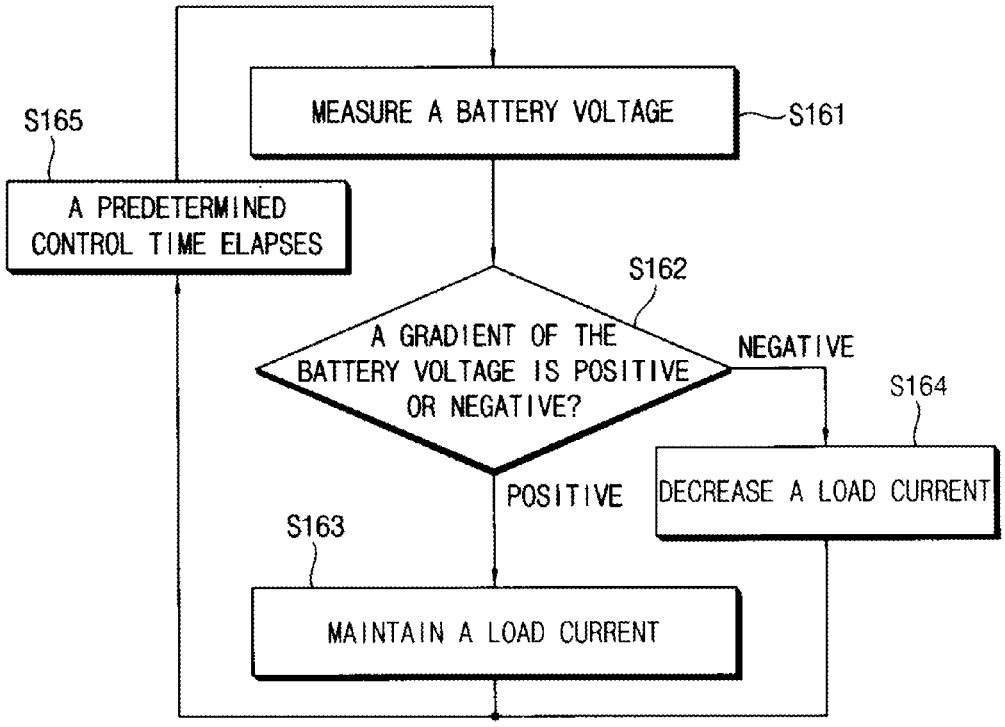

MEASURE A BATTERY VOLTAGE
S161
S165
A PREDETERMINED CONTROL TIME ELAPSES
S162
A GRADIENT OF THE BATTERY VOLTAGE IS POSITIVE OR NEGATIVE?
NEGATIVE
S164
DECREASE A LOAD CURRENT
POSITIVE
S163
MAINTAIN A LOAD CURRENT

FIG. 3

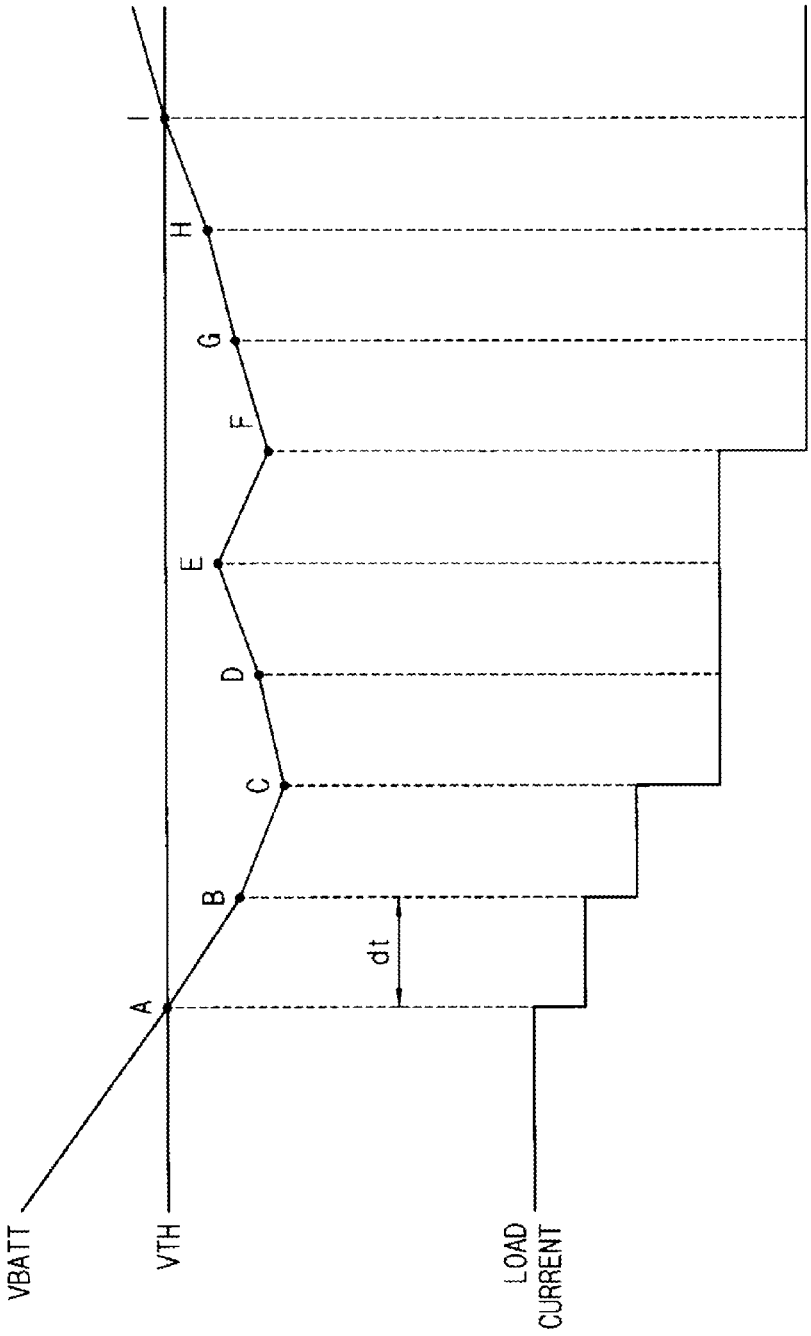


FIG. 4

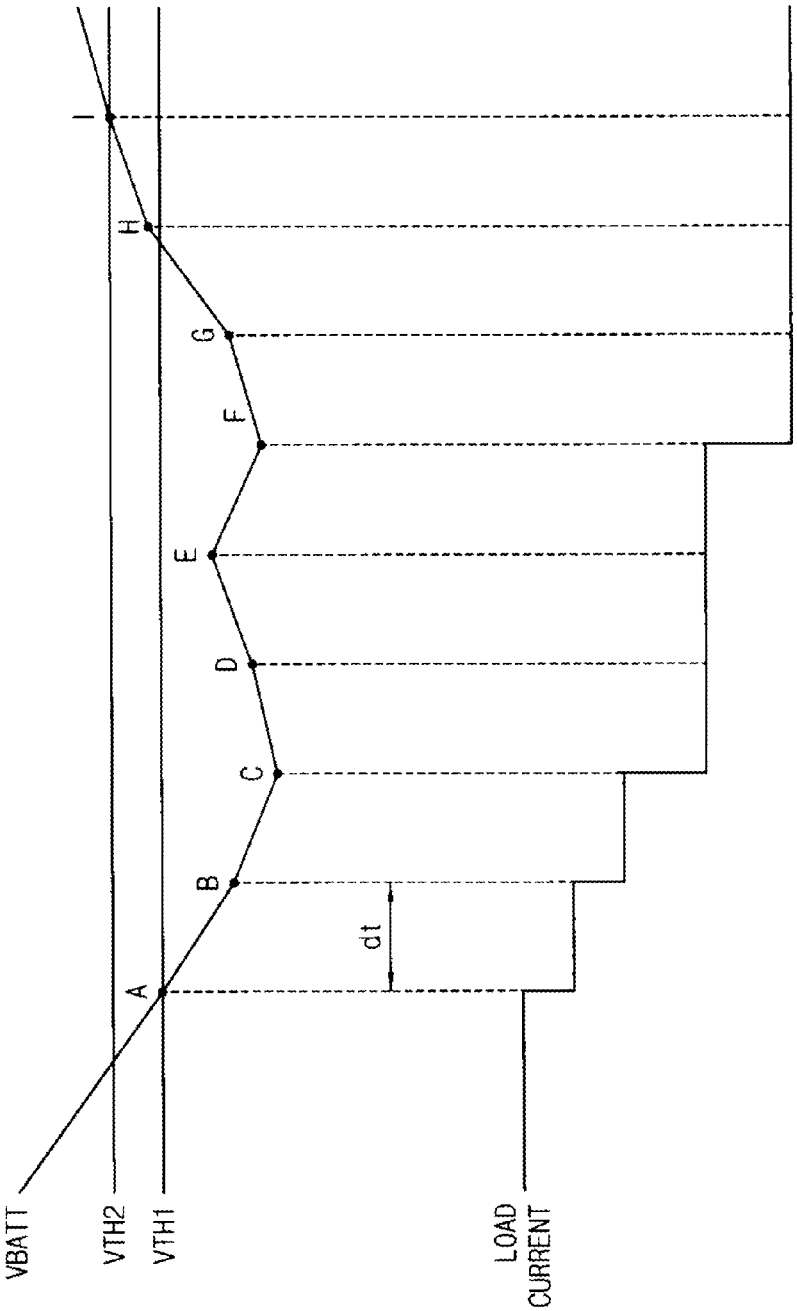


FIG. 5

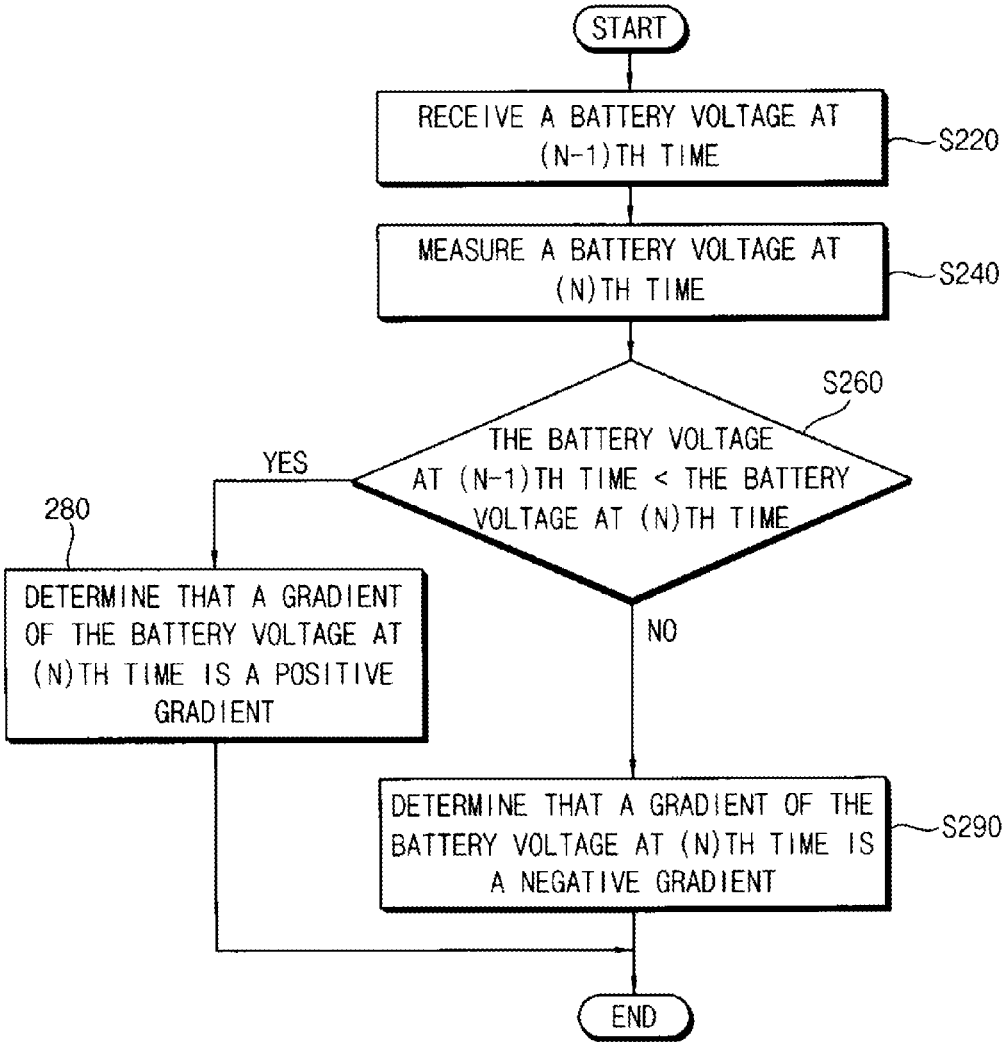

START
RECEIVE A BATTERY VOLTAGE AT (N-1)TH TIME
S220
MEASURE A BATTERY VOLTAGE AT (N)TH TIME
S240
S260
THE BATTERY VOLTAGE AT (N-1)TH TIME < THE BATTERY VOLTAGE AT (N)TH TIME
YES
NO
280
DETERMINE THAT A GRADIENT OF THE BATTERY VOLTAGE AT (N)TH TIME IS A POSITIVE GRADIENT
DETERMINE THAT A GRADIENT OF THE BATTERY VOLTAGE AT (N)TH TIME IS A NEGATIVE GRADIENT
S290
END

FIG. 6

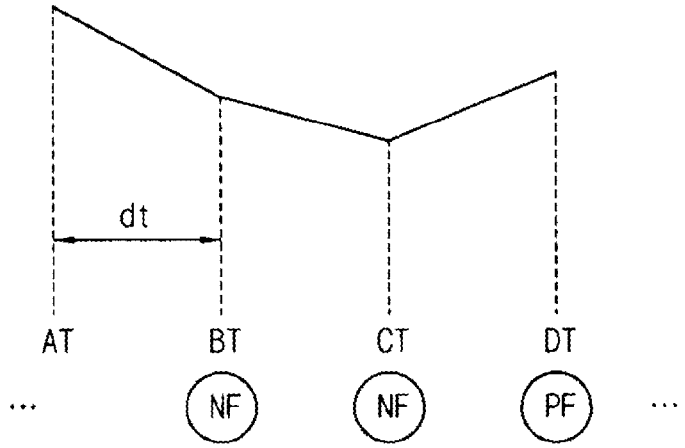

dt
AT
BT
CT
DT
...
NF
NF
PF
...

FIG. 7

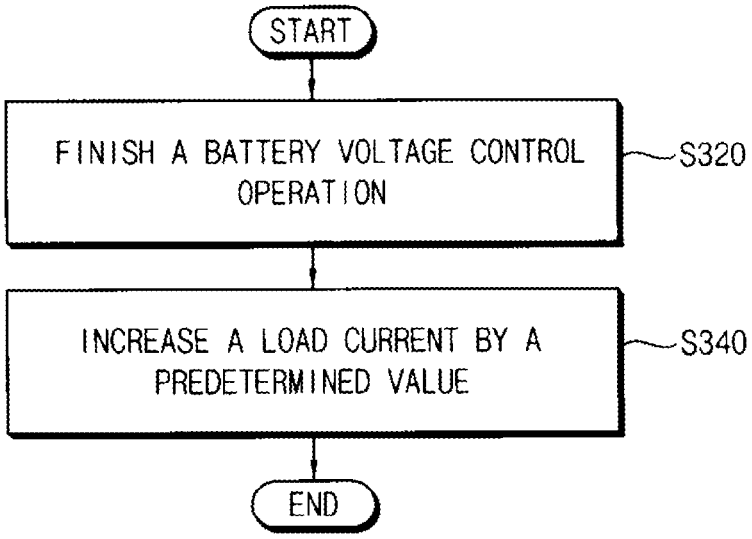

START
FINISH A BATTERY VOLTAGE CONTROL OPERATION
S320
INCREASE A LOAD CURRENT BY A PREDETERMINED VALUE
S340
END

FIG. 8

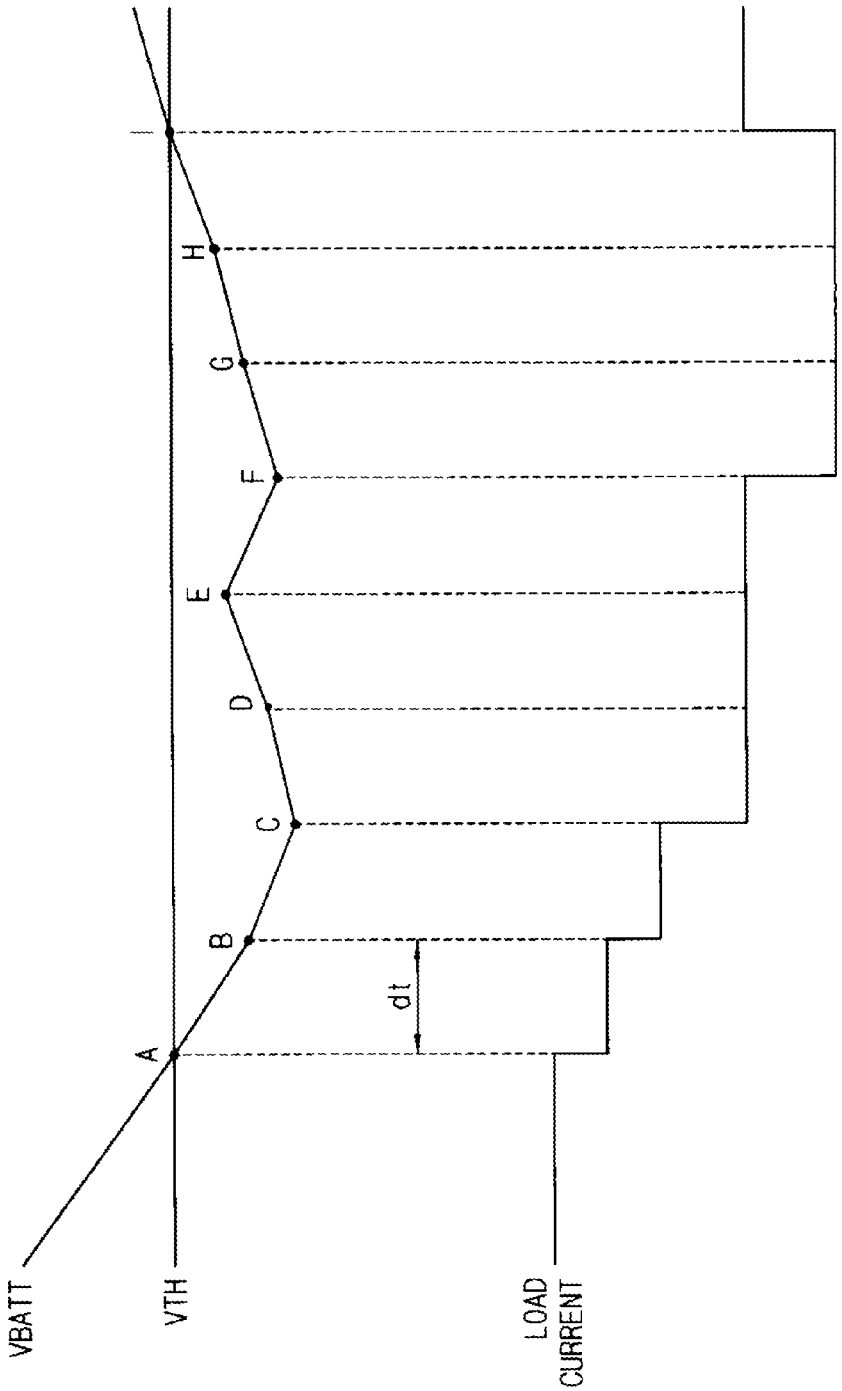


FIG. 9

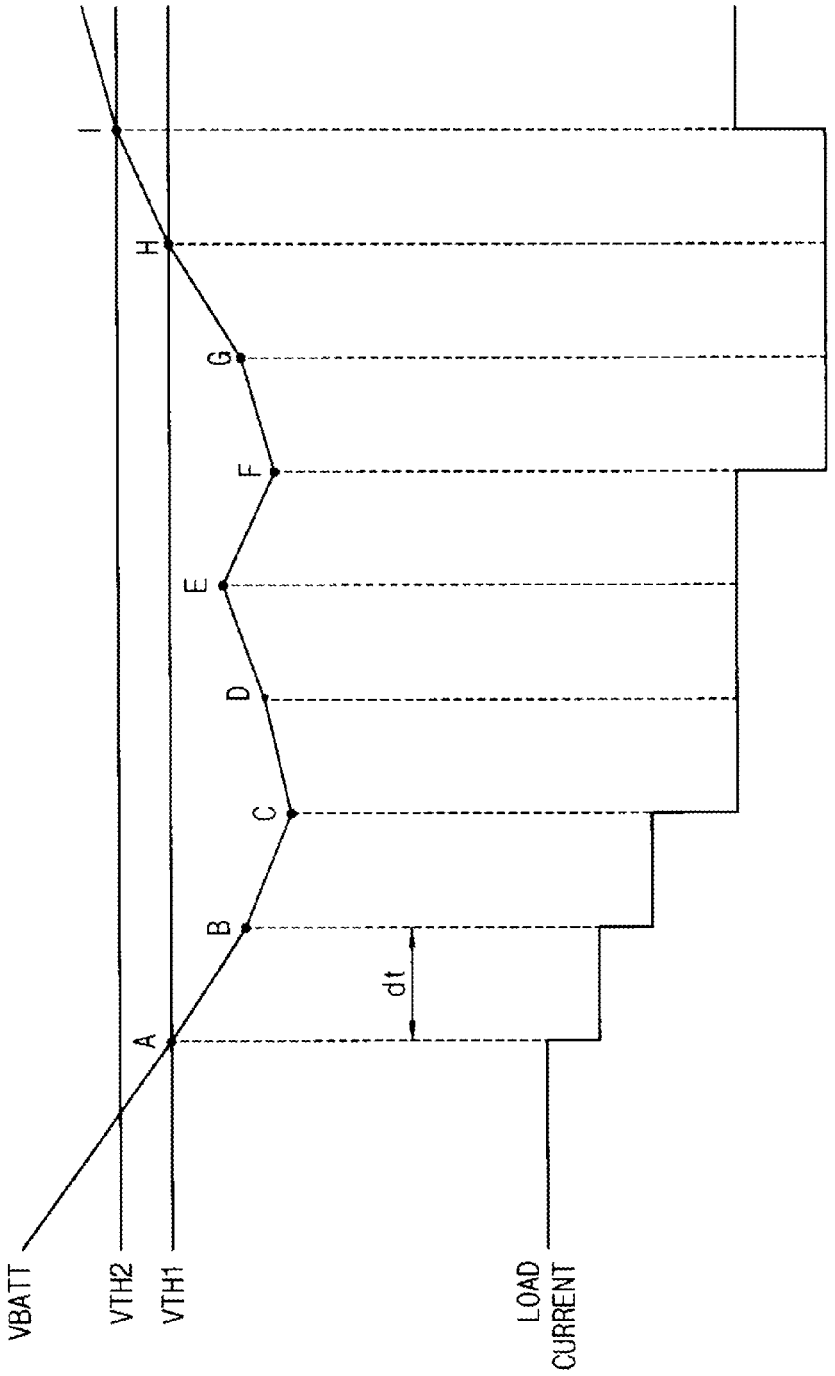


FIG. 10

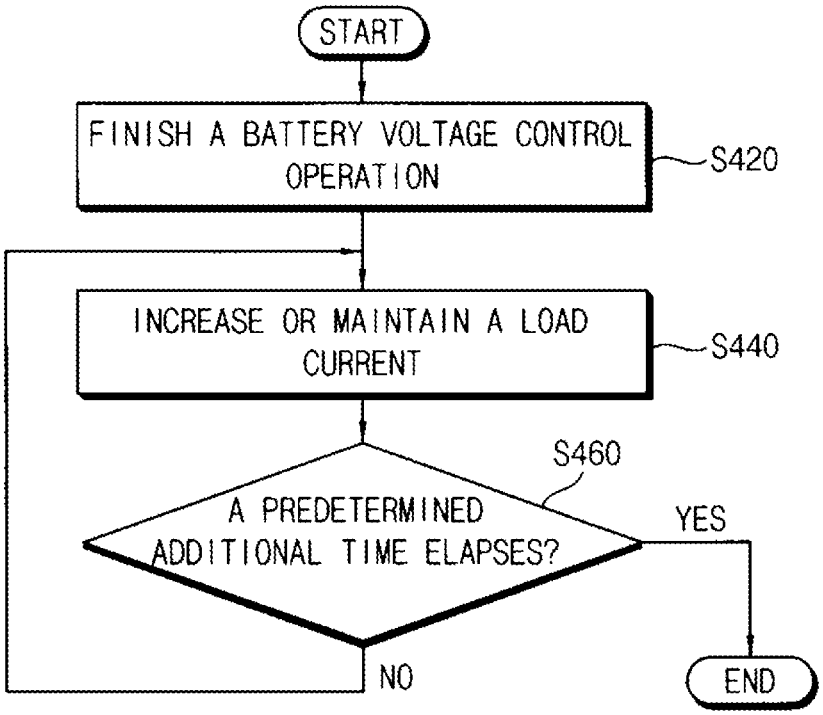

START
FINISH A BATTERY VOLTAGE CONTROL OPERATION
S420
INCREASE OR MAINTAIN A LOAD CURRENT
S440
S460
A PREDETERMINED ADDITIONAL TIME ELAPSES?
YES
NO
END

FIG. 11

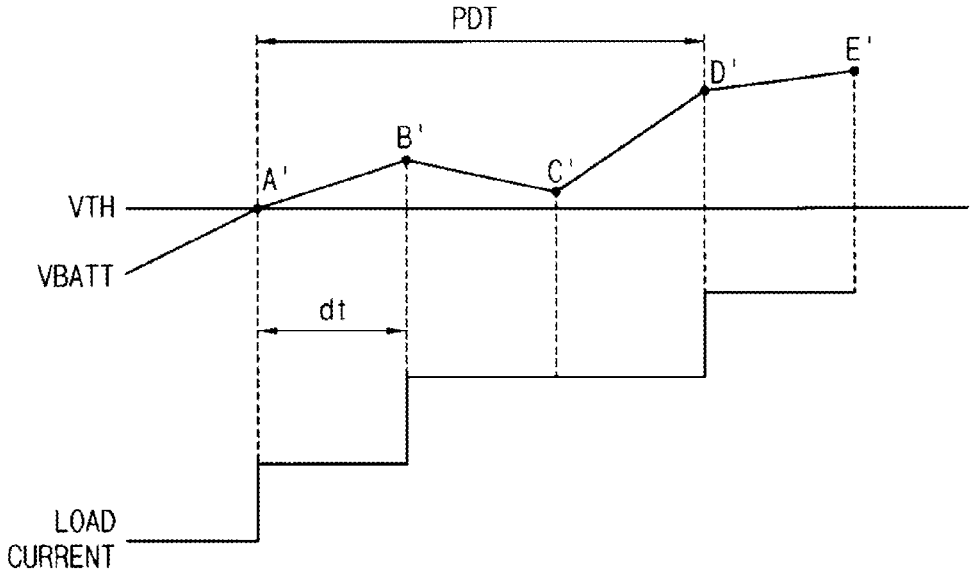

PDT
A'
B'
C'
D'
E'
VTH
VBATT
dt
LOAD
CURRENT

FIG. 12

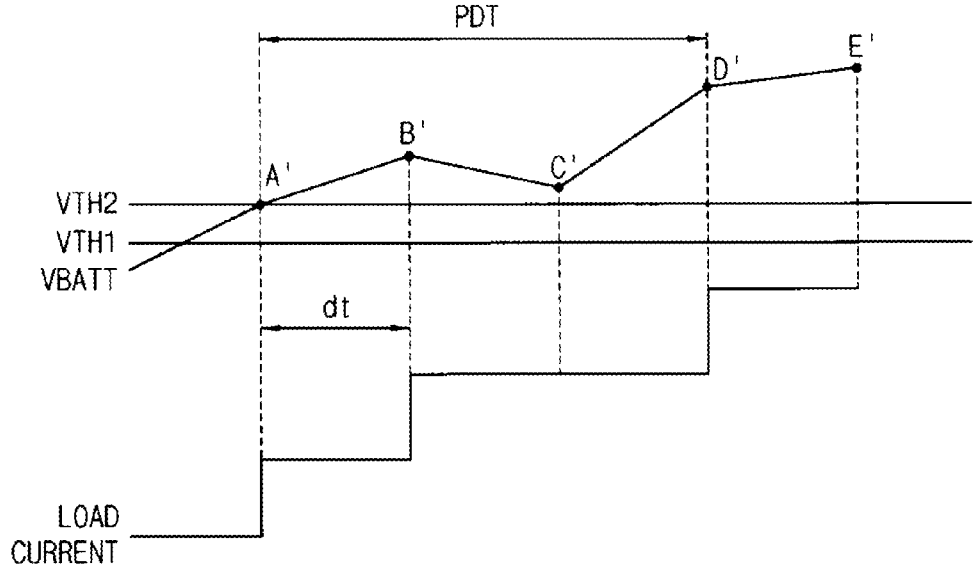

PDT
A'
B'
C'
D'
E'
VTH2
VTH1
VBATT
dt
LOAD
CURRENT

FIG. 13

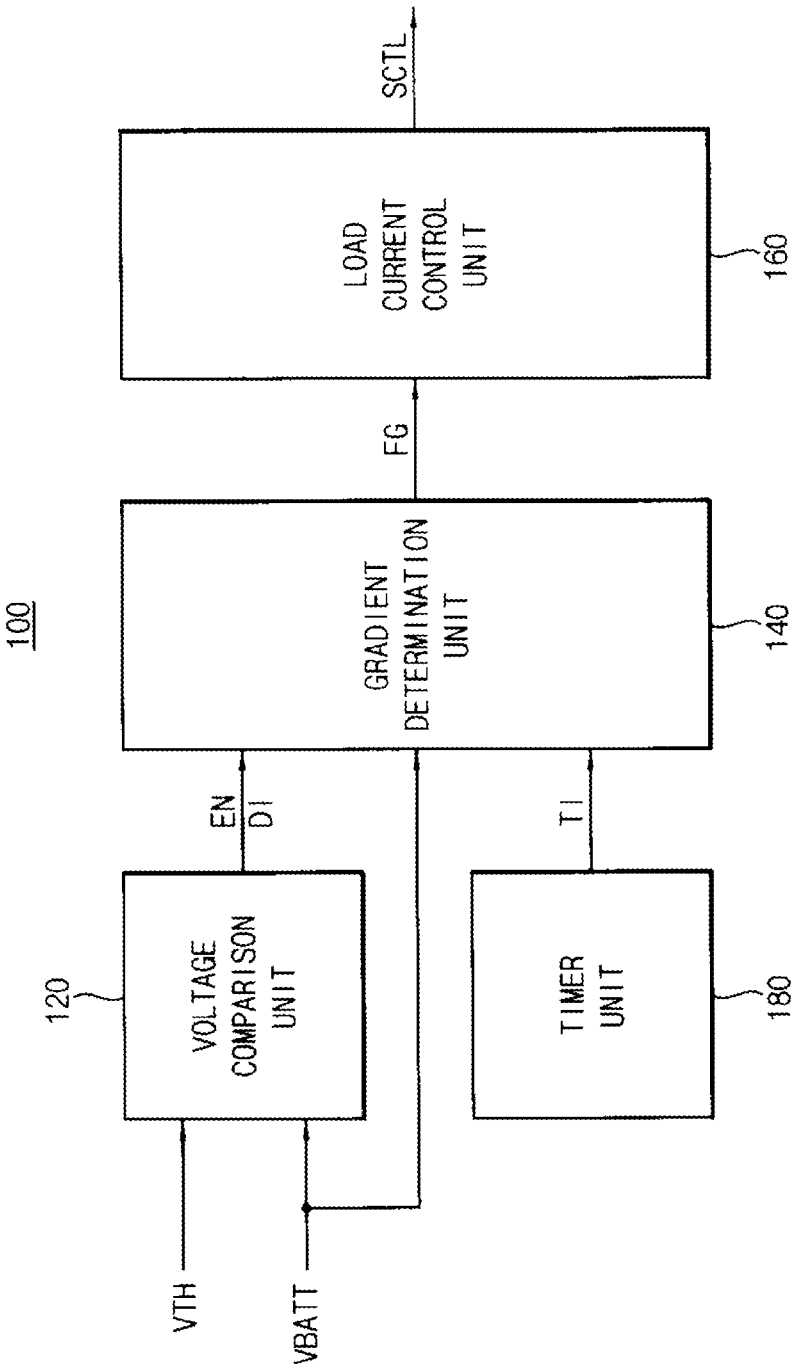

100
SCTL
LOAD CURRENT CONTROL UNIT
160
FG
GRADIENT DETERMINATION UNIT
140
EN
DI
TI
120
VOLTAGE COMPARISON UNIT
TIMER UNIT
180
VTH
VBATT

FIG. 14

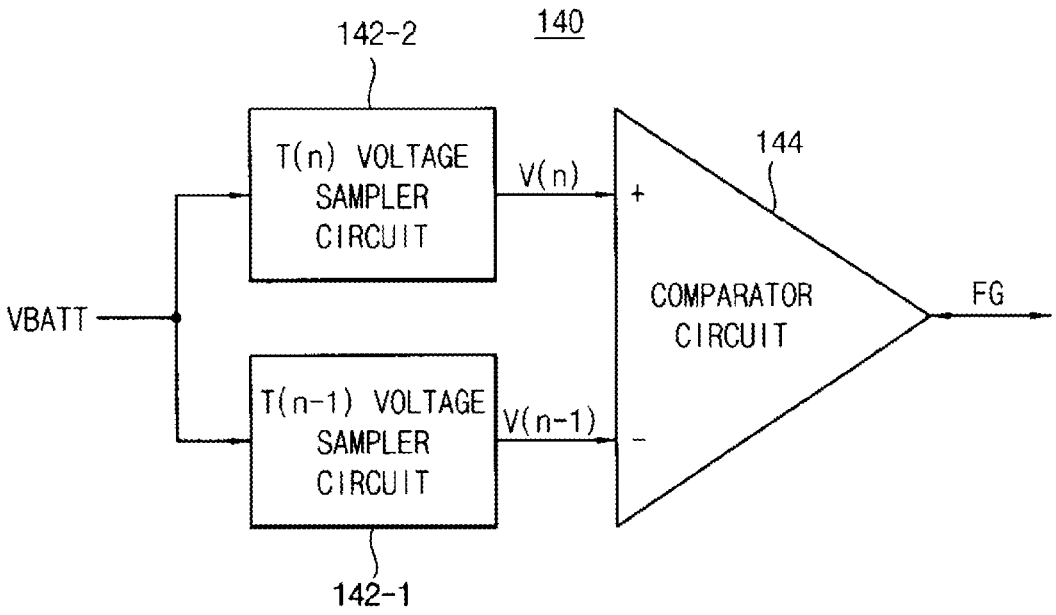

142-2
140
T(n) VOLTAGE SAMPLER CIRCUIT
V(n)
144
+
COMPARATOR CIRCUIT
FG
VBATT
T(n-1) VOLTAGE SAMPLER CIRCUIT
V(n-1)
-
142-1

FIG. 15

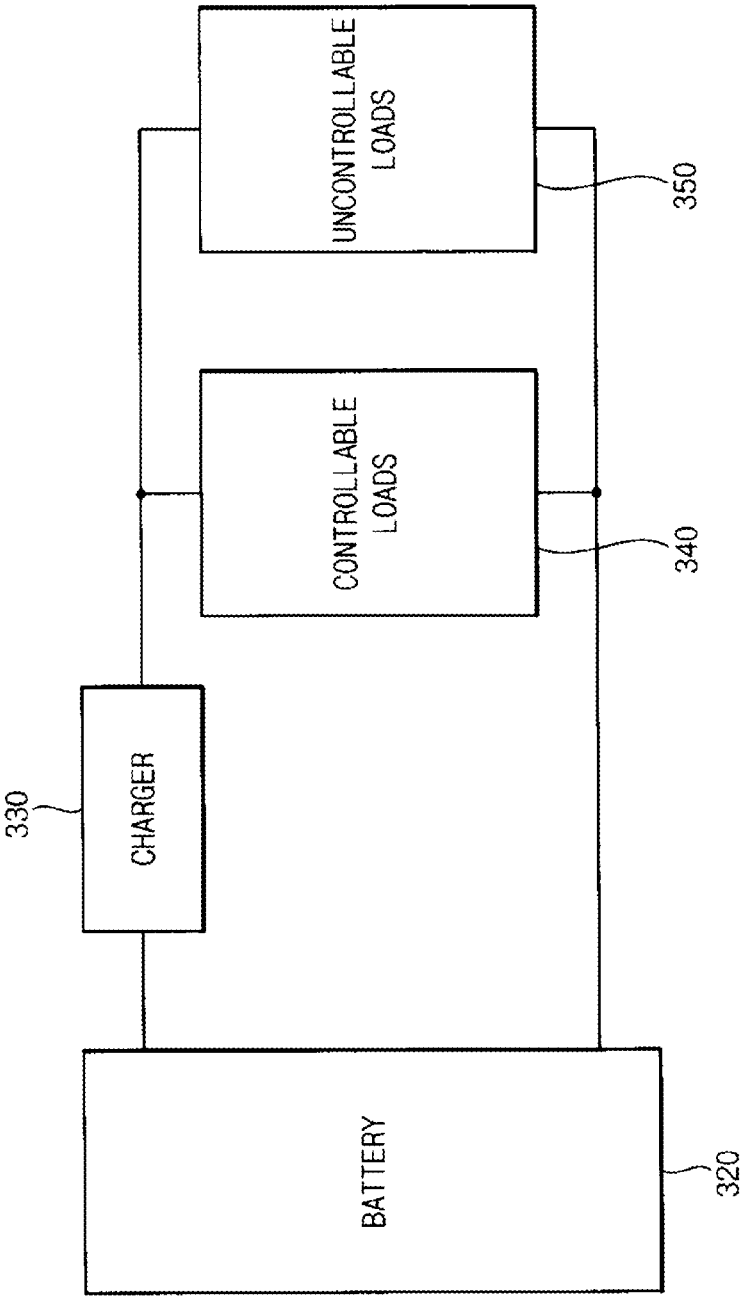

300
UNCONTROLLABLE LOADS
350
CONTROLLABLE LOADS
340
CHARGER
330
BATTERY
320

FIG. 16

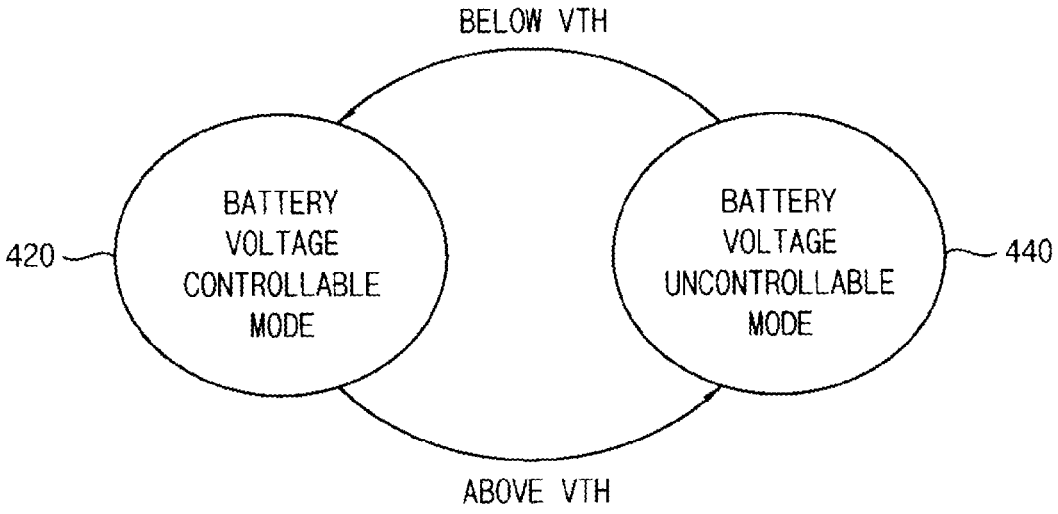

BELOW VTH
BATTERY VOLTAGE CONTROLLABLE MODE
420
BATTERY VOLTAGE UNCONTROLLABLE MODE
440
ABOVE VTH

FIG. 17

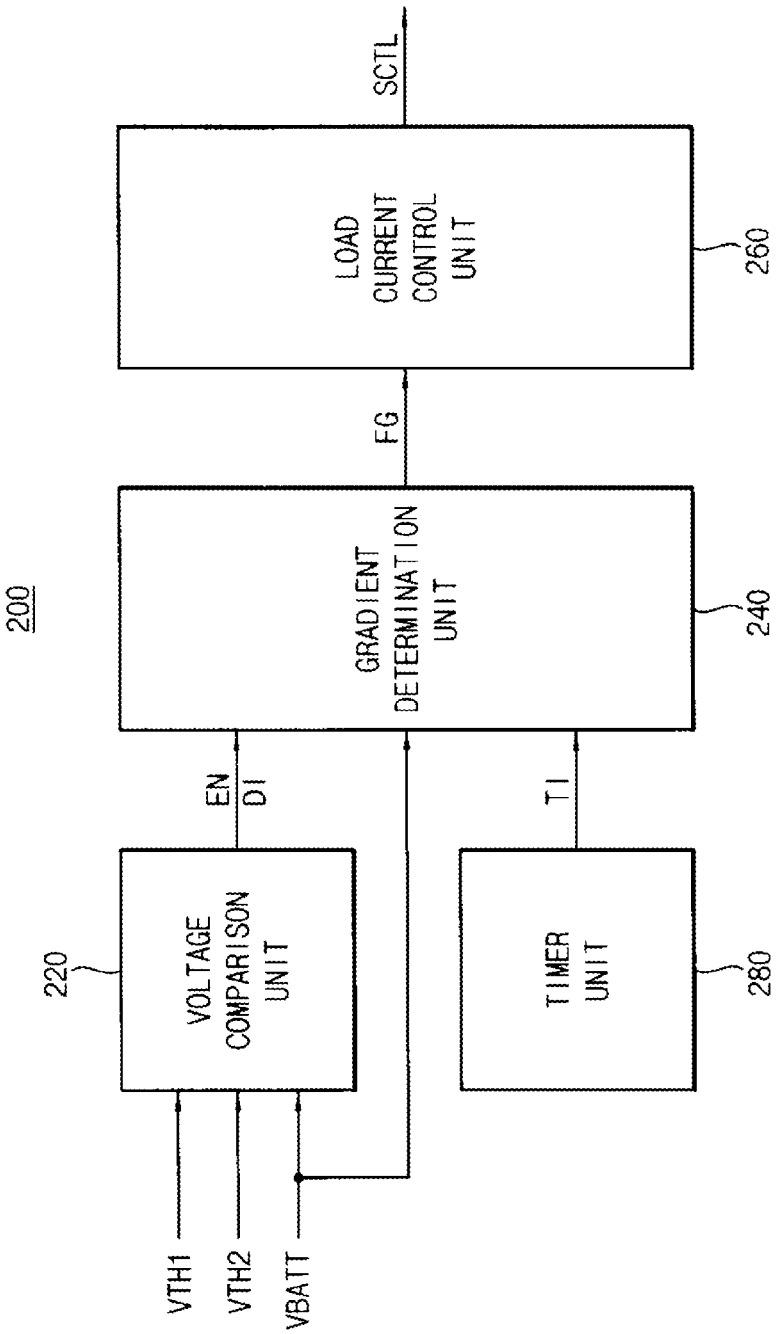

200
LOAD CURRENT CONTROL UNIT
260
SCTL
FG
GRADIENT DETERMINATION UNIT
240
EN
DI
TI
VOLTAGE COMPARISON UNIT
220
TIMER UNIT
280
VTH1
VTH2
VBATT

FIG. 18

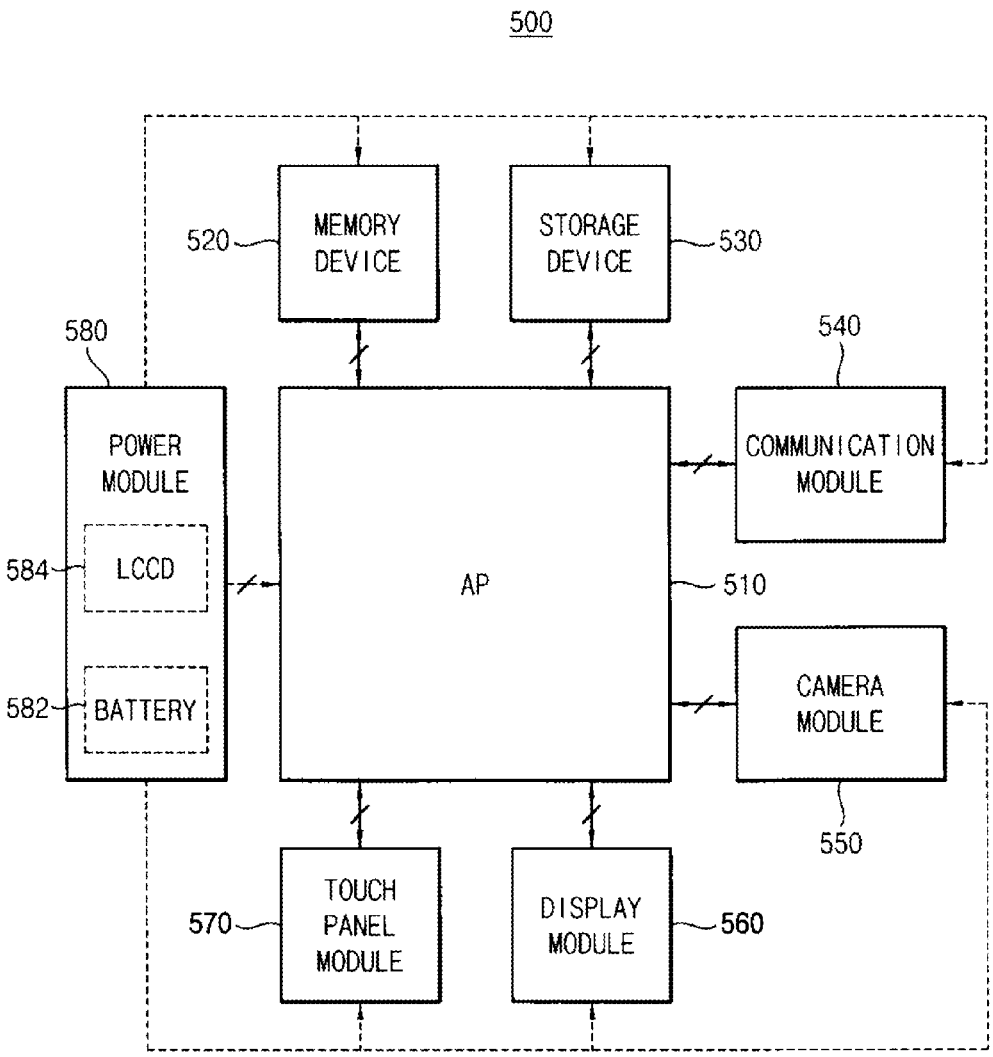

500
520
MEMORY DEVICE
STORAGE DEVICE
530
580
540
POWER MODULE
COMMUNICATION MODULE
584
LCCD
AP
510
582
BATTERY
CAMERA MODULE
550
570
TOUCH PANEL MODULE
DISPLAY MODULE
560

FIG. 19

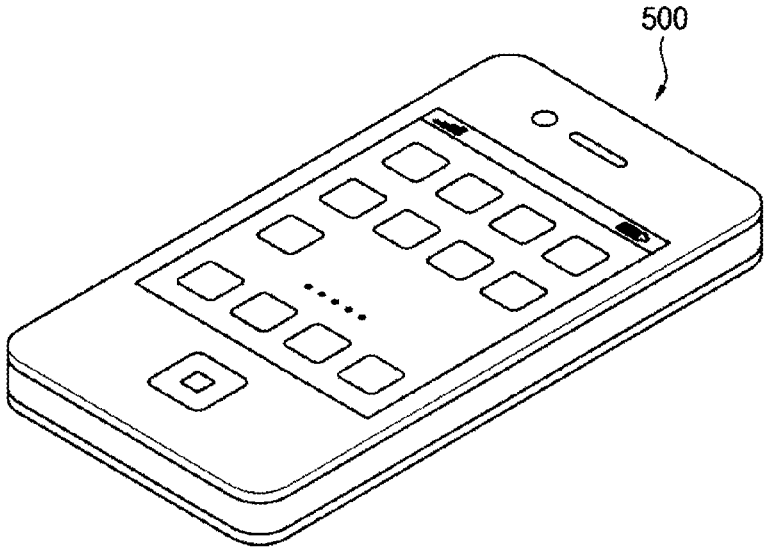
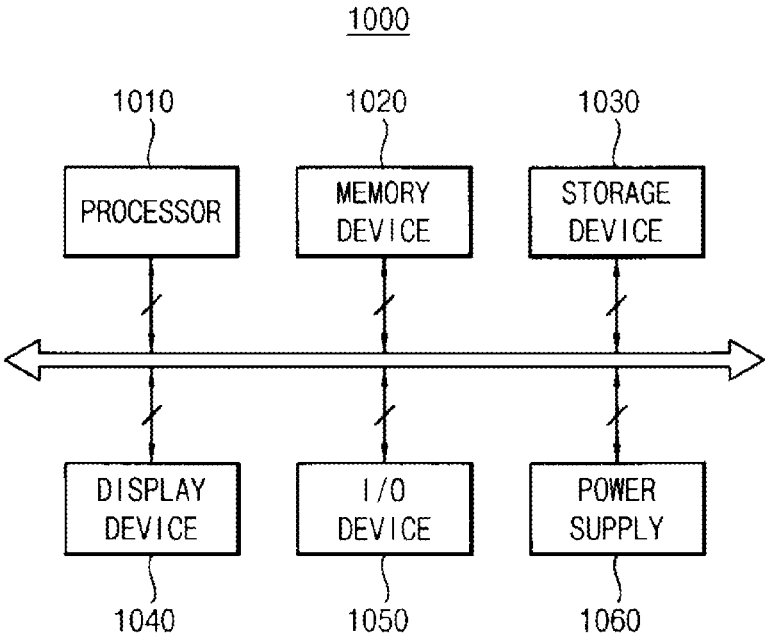

500

FIG. 20


1000
1010
1020
1030
PROCESSOR
MEMORY DEVICE
STORAGE DEVICE
DISPLAY DEVICE
I/O DEVICE
POWER SUPPLY
1040
1050
1060

METHOD OF CONTROLLING A LOAD CURRENT, LOAD CURRENT CONTROL DEVICE, AND MOBILE DEVICE HAVING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims priority under 35 USC §119 to Korean Patent Applications No. 10-2012-0087074, filed on Aug. 9, 2012 in the Korean Intellectual Property Office (KIPO), the entire contents of which are incorporated herein by reference.

BACKGROUND

1. Technical Field

Example embodiments of the inventive concepts relate generally to a battery power management technique. For example, embodiments of the inventive concepts relate to a method of controlling a load current, a load current control device, and a mobile device having the load current control device.

2. Description of the Related Art

Recently, according to a mobile convergence trend, a mobile device is manufactured in a small size, and a plurality of function modules that perform various functions (e.g., a communication function, a camera function, etc) may be integrated in the mobile device. However, since the mobile device is manufactured in a small size, it may be difficult to increase a capacity of a battery included in the mobile device, where the battery provides internal voltages to internal components (e.g., a memory device, a storage device, function modules, etc) of the mobile device. Thus, battery power management techniques for the mobile device may become more important because the mobile device needs to perform various functions using a battery having a limited capacity.

SUMMARY

Some example embodiments of the inventive concepts provide a method of controlling a load current capable of preventing an instantaneous, or relatively brief, sharp decrease of a battery voltage when loads instantaneously, or within a relatively short period of time, use a large load current.

Some example embodiments of the inventive concepts provide a load current control device capable of preventing an instantaneous, or relatively brief, sharp decrease of a battery voltage when loads instantaneously, or within a relatively short period of time, use a large load current.

Some example embodiments of the inventive concepts provide a mobile device having the load current control device capable of achieving a high operational stability (or, reliability).

According to some example embodiments of the inventive concepts, a method of controlling a load current may include a step of beginning a battery voltage control operation when a battery voltage becomes lower than a first threshold value, a step of determining whether a gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference or, alternatively, predetermined control time, a step of controlling the load current based on the gradient of the battery voltage at an interval of the reference or, alternatively, predetermined control time, and a step of finishing the battery voltage control operation when the battery voltage becomes higher than a second threshold value.

In example embodiments of the inventive concepts, the first threshold value may be equal to the second threshold value.

In example embodiments of the inventive concepts, the first threshold value may be different from the second threshold value.

In example embodiments of the inventive concepts, the step of determining whether the gradient of the battery voltage is the positive gradient or the negative gradient may include a step of measuring the battery voltage at a first time, a step of measuring the battery voltage at a second time, the second time being the time when the reference or, alternatively, predetermined control time elapses after the first time, a step of determining that the gradient of the battery voltage is the negative gradient when the battery voltage at the first time is greater than the battery voltage at the second time, and a step of determining that the gradient of the battery voltage is the positive gradient when the battery voltage at the first time is smaller than the battery voltage at the second time.

In example embodiments of the inventive concepts, the step of controlling the load current may include a step of decreasing the load current when the gradient of the battery voltage is determined to be the negative gradient, and a step of maintaining the load current when the gradient of the battery voltage is determined to be the positive gradient.

In example embodiments of the inventive concepts, the method of controlling the load current may further include a step of increasing the load current after the battery voltage control operation is finished.

In example embodiments of the inventive concepts, the load current may be increased one time after the battery voltage control operation is finished.

In example embodiments of the inventive concepts, the load current may be increased one or more times during a reference or, alternatively, predetermined addition time after the battery voltage control operation is finished.

According to some example embodiments of the inventive concepts, a load current control device may include a voltage comparison unit that decides whether or not to perform a battery voltage control operation by comparing a battery voltage with a threshold value, a gradient determination unit that determines whether a gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation, a load current control unit that controls a load current based on the gradient of the battery voltage at an interval of the reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation, and a timer unit that provides time information to the gradient determination unit at an interval of the reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation.

In example embodiments of the inventive concepts, the voltage comparison unit may provide an enabling signal for performing the battery voltage control operation to the gradient determination unit when the battery voltage becomes lower than the threshold value.

In example embodiments of the inventive concepts, the voltage comparison unit may provide a disenabling signal for finishing the battery voltage control operation to the gradient determination unit when the battery voltage becomes higher than the threshold value.

In example embodiments of the inventive concepts, the gradient determination unit may measure the battery voltage at a first time, may measure the battery voltage at a second

time, the second time being the time when the reference or, alternatively, predetermined control time elapses after the first time, and may compare the battery voltage at the first time with the battery voltage at the second time.

In example embodiments of the inventive concepts, the gradient determination unit may determine that the gradient of the battery voltage is the negative gradient when the battery voltage at the first time is greater than the battery voltage at the second time, and may determine that the gradient of the battery voltage is the positive gradient when the battery voltage at the first time is smaller than the battery voltage at the second time.

In example embodiments of the inventive concepts, the load current control unit may decrease the load current when the gradient of the battery voltage is determined to be the negative gradient, and may maintain the load current when the gradient of the battery voltage is determined to be the positive gradient.

In example embodiments of the inventive concepts, the load current control unit may increase the load current after the battery voltage control operation is finished.

According to some example embodiments of the inventive concepts, a load current control device may include a voltage comparison unit that decides whether or not to perform a battery voltage control operation by comparing a battery voltage with a first threshold value and a second threshold value, the first threshold value being different from the second threshold value, a gradient determination unit that determines whether a gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation, a load current control unit that controls a load current based on the gradient of the battery voltage at an interval of the reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation, and a timer unit that provides time information to the gradient determination unit at an interval of the reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation.

In example embodiments of the inventive concepts, the voltage comparison unit may provide an enabling signal for performing the battery voltage control operation to the gradient determination unit when the battery voltage becomes lower than the first threshold value.

In example embodiments of the inventive concepts, the voltage comparison unit may provide a disenabling signal for finishing the battery voltage control operation to the gradient determination unit when the battery voltage becomes higher than the second threshold value.

In example embodiments of the inventive concepts, the gradient determination unit may measure the battery voltage at a first time, may measure the battery voltage at a second time, the second time being the time when the reference or, alternatively, predetermined control time elapses after the first time, and may compare the battery voltage at the first time with the battery voltage at the second time.

In example embodiments of the inventive concepts, the gradient determination unit may determine that the gradient of the battery voltage is the negative gradient when the battery voltage at the first time is greater than the battery voltage at the second time, and may determine that the gradient of the battery voltage is the positive gradient when the battery voltage at the first time is smaller than the battery voltage at the second time.

In example embodiments of the inventive concepts, the load current control unit may decrease the load current when the gradient of the battery voltage is determined to be the negative gradient, and may maintain the load current when the gradient of the battery voltage is determined to be the positive gradient.

In example embodiments of the inventive concepts, the load current control unit may increase the load current after the battery voltage control operation is finished.

According to some example embodiments of the inventive concepts, a mobile device may include an application processor, at least one memory device, at least one storage device, at least one function module, and a power module that provides a battery voltage to the application processor, the memory device, the storage device, and the function module. Here, the power module may include a battery that supplies the battery voltage and a load current control device that controls a load current based on a gradient of the battery voltage when performing a battery voltage control operation.

In example embodiments of the inventive concepts, the load current control device may perform the battery voltage control operation when the battery voltage becomes lower than a threshold value, and may finish the battery voltage control operation when the battery voltage becomes higher than the threshold value.

In example embodiments of the inventive concepts, the load current control device may perform the battery voltage control operation when the battery voltage becomes lower than a first threshold value, and may finish the battery voltage control operation when the battery voltage becomes higher than a second threshold value, the first threshold value being different from the second threshold value.

In example embodiments of the inventive concepts, at an interval of a reference or, alternatively, predetermined control time, the load current control device may decrease the load current by a reference or, alternatively, predetermined value when the gradient of the battery voltage is determined to be a negative gradient, and may maintain the load current when the gradient of the battery voltage is determined to be a positive gradient.

In example embodiments of the inventive concepts, the load current control device may determine whether the gradient of the battery voltage is the positive gradient or the negative gradient by comparing the battery voltage at a first time with the battery voltage at a second time, the second time being the time when the reference or, alternatively, predetermined control time elapses after the first time.

In example embodiments of the inventive concepts, the load current control device may increase the load current after the battery voltage control operation is finished.

Therefore, a method of controlling a load current according to example embodiments of the inventive concepts may prevent an instantaneous, or relatively brief, sharp decrease of a battery voltage by sensing a gradient of the battery voltage to control (i.e., decrease or maintain) the load current based on the gradient of the battery voltage when the battery voltage becomes (i.e., decreases) lower than a reference or, alternatively, predetermined threshold value as loads instantaneously, or within a relatively short period of time, use a large load current.

In addition, a load current control device according to example embodiments of the inventive concepts may prevent an instantaneous, or relatively brief, sharp decrease of a battery voltage by sensing a gradient of the battery voltage to control (i.e., decrease or maintain) the load current based on the gradient of the battery voltage when the battery voltage becomes lower than a reference or, alternatively, predeter-

mined threshold value as loads instantaneously, or within a relatively short period of time, use a large load current.

Further, a mobile device according to example embodiments of the inventive concepts may achieve a high operational stability by using the load current control device.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages of example embodiments will become more apparent by describing in detail example embodiments with reference to the attached drawings. The accompanying drawings are intended to depict example embodiments and should not be interpreted to limit the intended scope of the claims. The accompanying drawings are not to be considered as drawn to scale unless explicitly noted.

FIG. **1** is a flow chart illustrating a method of controlling a load current according to example embodiments of the inventive concepts.

FIG. **2** is a flow chart illustrating a process in which a load current is controlled by a method of FIG. **1**.

FIG. **3** is a diagram illustrating an example in which a load current is controlled by a method of FIG. **1**.

FIG. **4** is a diagram illustrating another example in which a load current is controlled by a method of FIG. **1**.

FIG. **5** is a flow chart illustrating a process in which a gradient of a battery voltage is sensed by a method of FIG. **1**.

FIG. **6** is a diagram illustrating an example in which a gradient of battery voltage is sensed by a method of FIG. **1**.

FIG. **7** is a flow chart illustrating a process in which a load current is increased one time after a battery voltage control operation is finished by a method of FIG. **1**.

FIG. **8** is a diagram illustrating an example in which a load current is increased one time after a battery voltage control operation is finished by a method of FIG. **1**.

FIG. **9** is a diagram illustrating another example in which a load current is increased one time after a battery voltage control operation is finished by a method of FIG. **1**.

FIG. **10** is a flow chart illustrating a process in which a load current is increased one or more times during a reference or, alternatively, predetermined additional time after a battery voltage control operation is finished by a method of FIG. **1**.

FIG. **11** is a diagram illustrating an example in which a load current is increased one or more times during a reference or, alternatively, predetermined additional time after a battery voltage control operation is finished by a method of FIG. **1**.

FIG. **12** is a diagram illustrating another example in which a load current is increased one or more times during a reference or, alternatively, predetermined additional time after a battery voltage control operation is finished by a method of FIG. **1**.

FIG. **13** is a block diagram illustrating a load current control device according to example embodiments of the inventive concepts.

FIG. **14** is a block diagram illustrating a gradient determination unit included in a load current control device of FIG. **13**.

FIG. **15** is a block diagram illustrating a battery voltage control operation that is performed by a load current control device of FIG. **13**.

FIG. **16** is a concept diagram illustrating a battery voltage control operation that is performed by a load current control device of FIG. **13**.

FIG. **17** is a block diagram illustrating a load current control device according to example embodiments of the inventive concepts.

FIG. **18** is a block diagram illustrating a mobile device having a load current control device according to example embodiments of the inventive concepts.

FIG. **19** is a block diagram illustrating an example in which a mobile device of FIG. **18** is implemented as a smart-phone.

FIG. **20** is a block diagram illustrating an electronic device having a load current control device according to example embodiments of the inventive concepts.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Various example embodiments of the inventive concepts will be described more fully hereinafter with reference to the accompanying drawings, in which some example embodiments of the inventive concepts are shown. The present inventive concept may, however, be embodied in many different forms and should not be construed as limited to the example embodiments of the inventive concepts set forth herein. Rather, these example embodiments of the inventive concepts are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present inventive concept to those skilled in the art. In the drawings, the sizes and relative sizes of layers and regions may be exaggerated for clarity. Like numerals refer to like elements throughout.

It will be understood that, although the terms first, second, third etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are used to distinguish one element from another. Thus, a first element discussed below could be termed a second element without departing from the teachings of the present inventive concept. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.).

The terminology used herein is for the purpose of describing particular example embodiments of the inventive concepts only and is not intended to be limiting of the present inventive concept. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this inventive concept belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

In the mobile device, when internal components (i.e., referred to as loads) instantaneously, or within a relatively short period of time, use a large load current, a voltage of the battery (hereinafter, battery voltage) may instantaneously, or within a relatively short period of time, fall into a battery operation-disabled region although an actual battery voltage is in a battery operation-enabled region. Here, the battery operation-disabled region indicates a region below a minimum voltage, where the battery is determined to be a system shutdown battery when a battery voltage is in the region below the minimum voltage. In other words, when the loads of the mobile device instantaneously, or within a relatively short period of time, use the large load current, the mobile device may malfunction, or may stop performing various functions. Therefore, when the loads of the mobile device instantaneously, or within a relatively short period of time, use the large load current, the mobile device is required to prevent an instantaneous, or relatively brief, sharp decrease of the battery voltage.

FIG. **1** is a flow chart illustrating a method of controlling a load current according to example embodiments of the inventive concepts.

Referring to FIG. **1**, the method of FIG. **1** may begin a battery voltage control operation when a battery voltage becomes (i.e., decreases) lower than a first threshold value (Step S**120**), may sense a gradient of the battery voltage (i.e., may determine whether the gradient of the battery voltage is a positive gradient or a negative gradient) at an interval of a reference or, alternatively, predetermined control time (Step S**140**), may control a load current based on the gradient of the battery voltage at an interval of the reference or, alternatively, predetermined control time (Step S**160**), and may finish the battery voltage control operation when the battery voltage becomes (i.e., increases) higher than a second threshold value (Step S**180**).

Generally, in an electronic device (e.g., a mobile device) that operates based on a battery, when a plurality of loads instantaneously, or within a relatively short period of time, use a large load current, a battery voltage may instantaneously, or within a relatively short period of time, fall into a battery operation-disabled region although an actual battery voltage is in a battery operation-enabled region. As a result, when the loads instantaneously, or within a relatively short period of time, use the large load current, the electronic device may malfunction, or may stop performing various functions. Thus, when the loads of the electronic device instantaneously, or within a relatively short period of time, use the large load current, the electronic device is required to prevent an instantaneous, or relatively brief, sharp decrease of the battery voltage. The electronic device may include a plurality of controllable loads of which the load current can be controlled and a plurality of uncontrollable loads of which the load current cannot be controlled. For example, the controllable loads may correspond to an LED driver, an internal function module, etc, and the uncontrollable loads may correspond to an external function module (e.g., function modules of other chips). Thus, it should be understood that the method of FIG. **1** indirectly controls the load current used by the uncontrollable loads by controlling the load current used by the controllable loads as well as the method of FIG. **1** directly controls the load current used by the controllable loads.

The method of FIG. **1** may begin the battery voltage control operation when the battery voltage becomes lower than the first threshold value (Step S**120**). Here, the first threshold value corresponds to a reference value that is compared with the battery voltage in order to decide whether or not to perform the battery voltage control operation. To prevent the battery voltage from falling into the battery operation-disabled region, the first threshold value may be set to be higher than the minimum voltage, where the battery is determined to be a system shutdown battery when the battery voltage is lower than the minimum voltage. That is, the method of FIG. **1** may decide whether or not to perform the battery voltage control operation by comparing the battery voltage with the first threshold value. As described below, the method of FIG. **1** may perform the battery voltage control operation by controlling (i.e., decreasing or maintaining) the load current used by the loads. For example, the method of FIG. **1** may decrease or maintain the load current when the loads instantaneously, or within a relatively short period of time, use the large load current. As a result, the method of FIG. **1** may efficiently prevent the battery voltage from falling into the battery operation-disabled region.

The method of FIG. **1** may sense the gradient of the battery voltage (i.e., may determine whether the gradient of the battery voltage is the positive gradient or the negative gradient) at an interval of the reference or, alternatively, predetermined control time (Step S**140**), and may control the load current based on the gradient of the battery voltage at an interval of the reference or, alternatively, predetermined control time (Step S**160**). That is, the method of FIG. **1** may control (i.e., decrease or maintain) the load current at an interval of the reference or, alternatively, predetermined control time while performing the battery voltage control operation. Here, the reference or, alternatively, predetermined control time may be variously determined according to required conditions for the electronic device. For example, when the reference or, alternatively, predetermined control time is determined to be relatively short, an accuracy of the battery voltage control operation may be improved. However, the battery voltage control operation may be a heavy burden on the electronic device because the number of times controlling the load current is greatly increased. On the other hand, when the reference or, alternatively, predetermined control time is determined to be relatively long, the battery voltage control operation may be a slight burden on the electronic device because the number of times controlling the load current is greatly decreased. However, an accuracy of the battery voltage control operation may be degraded. Therefore, the method of FIG. **1** may efficiently perform the battery voltage control operation by adjusting the reference or, alternatively, predetermined control time based on the above trade-off relation.

The method of FIG. **1** may determine whether the gradient of the battery voltage is the positive gradient or the negative gradient. Specifically, the method of FIG. **1** may measure the battery voltage at a first time, and may measure the battery voltage at a second time, where the second time is the time when the reference or, alternatively, predetermined control time elapses after the first time. Then, the method of FIG. **1** may determine that the gradient of the battery voltage is the negative gradient if the battery voltage at the first time is greater than the battery voltage at the second time, and may determine that the gradient of the battery voltage is the positive gradient if the battery voltage at the first time is smaller than the battery voltage at the second time. Subsequently, the method of FIG. **1** may decrease the load current flowing through the loads when determining that the gradient of the battery voltage is the negative gradient, and may maintain the load current flowing through the loads when determining that the gradient of the battery voltage is the positive gradient. Accordingly, compared to conventional methods, the method of FIG. **1** may efficiently perform the battery voltage control

operation by controlling (i.e., decrease or maintain) the load current based on the gradient of the battery voltage.

The method of FIG. **1** may finish the battery voltage control operation when the battery voltage becomes (i.e., increases) higher than the second threshold value (Step S**180**). In one example embodiment, the first threshold value may be equal to the second threshold value. In this case, the threshold value for deciding whether or not to begin the battery voltage control operation may be equal to the threshold value for deciding whether or not to finish the battery voltage control operation. In another example embodiment, the first threshold value may be different from the second threshold value. In this case, a hysteresis range may exist between the threshold value for deciding whether or not to begin the battery voltage control operation and the threshold value for deciding whether or not to finish the battery voltage control operation. In example embodiments of the inventive concepts, the first and second threshold values may be related such that the first threshold value may be smaller than the second threshold value. However, example embodiments of the inventive concepts are not limited to this relationship. Thus, in some example embodiments of the inventive concepts, the first threshold value may be greater than the second threshold value. In addition, the method of FIG. **1** may increase the load current flowing through the loads after finishing the battery voltage control operation. That is, the method of FIG. **1** may increase the load current flowing through the loads to an optimal level after preventing the battery voltage from instantaneously, or within a relatively short period of time, falling into the battery operation-disabled region. To this end, the method of FIG. **1** may increase the load current flowing through the loads one time after finishing the battery voltage control operation. Alternatively, the method of FIG. **1** may increase the load current flowing through the loads one or more times during a reference or, alternatively, predetermined additional time after finishing the battery voltage control operation. These operations will be described with reference to FIGS. **7** through **12**.

As described above, the method of FIG. **1** may prevent an instantaneous, or relatively brief, sharp decrease of the battery voltage by sensing the gradient of the battery voltage to control (i.e., decrease or maintain) the load current based on the gradient of the battery voltage when the battery voltage becomes lower than a reference or, alternatively, predetermined threshold value (i.e., the first threshold value) as the loads of the electronic device instantaneously, or within a relatively short period of time, use the large load current. Since the conventional methods (i.e., conventional load current control techniques) continuously decrease the load current flowing through the loads when the battery voltage becomes lower than the reference or, alternatively, predetermined threshold value, the conventional methods may excessively decrease the load current flowing through the loads although the load current flowing through the loads is sufficiently reduced (i.e., although there is no need to decrease the load current flowing through the loads). On the other hand, by controlling (i.e., decreasing or maintaining) the load current flowing through the loads based on the gradient of the battery voltage, the method of FIG. **1** may not decrease the load current flowing through the loads when the load current flowing through the loads is sufficiently reduced. As a result, the method of FIG. **1** may properly decrease the load current flowing through the loads as well as efficiently preventing the battery voltage from falling into the battery operation-disabled region.

FIG. **2** is a flow chart illustrating a process in which a load current is controlled by a method of FIG. **1**.

Referring to FIG. **2**, it is illustrated that the method of FIG. **1** controls (i.e., decreases or maintains) the load current at an interval of a reference or, alternatively, predetermined control time when performing a battery voltage control operation. Specifically, when performing the battery voltage control operation S**160**, the method of FIG. **1** may measure a battery voltage at an (n)th time (Step S**161**), and may determine whether a gradient of the battery voltage at the (n)th time is a positive gradient or a negative gradient (Step S**162**). As described above, the method of FIG. **1** may determine whether the gradient of the battery voltage at the (n)th time is the positive gradient or the negative gradient by comparing the battery voltage at an (n−1)th time with the battery voltage at the (n)th time, where the (n)th time is the time when the reference or, alternatively, predetermined control time elapses after the (n−1)th time. For example, the method of FIG. **1** may determine that the gradient of the battery voltage at the (n)th time is the negative gradient if the battery voltage at the (n−1)th time is greater than the battery voltage at the (n)th time, and may determine that the gradient of the battery voltage at the (n)th time is the positive gradient if the battery voltage at the (n−1)th time is smaller than the battery voltage at the (n)th time.

The method of FIG. **1** may maintain the load current flowing through the loads (Step S**163**) when determining that the gradient of the battery voltage at the (n)th time is the positive gradient, and may decrease the load current flowing through the loads (Step S**164**) when determining that the gradient of the battery voltage at the (n)th time is the negative gradient. Subsequently, the method of FIG. **1** may measure the battery voltage at an (n+1)th time, where the (n+1)th time is the time when the reference or, alternatively, predetermined control time elapses after the (n)th time (Step S**161**) when the reference or, alternatively, predetermined control time elapses (Step S**165**) after the load current is controlled at the (n)th time. Similarly, the method of FIG. **1** may determine whether the gradient of the battery voltage at the (n+1)th time is the positive gradient or the negative gradient (Step S**162**), and then may control the load current based on the determination result at the (n+1)th time (Step S**163**, Step S**164**). In this way, the method of FIG. **1** may repeatedly control the load current at an interval of the reference or, alternatively, predetermined control time. As a result, the method of FIG. **1** may prevent the battery voltage from falling into the battery operation-disabled region when the loads instantaneously, or within a relatively short period of time, use a large load current.

FIG. **3** is a diagram illustrating an example in which a load current is controlled by a method of FIG. **1**.

Referring to FIG. **3**, the method of FIG. **1** may begin a battery voltage control operation (i.e., indicated as a point A) when a battery voltage VBATT becomes lower than a threshold value VTH as a plurality of loads of an electronic device instantaneously, or within a relatively short period of time, use a large load current. As a result, a monitoring operation on the battery voltage VBATT may be begun when the battery voltage control operation is begun. Here, the method of FIG. **1** may not continuously check the battery voltage VBATT. Thus, the method of FIG. **1** may check (i.e., sample) the battery voltage VBATT only at points A through I. On this basis, the method of FIG. **1** may determine whether a gradient of the battery voltage VBATT is a positive gradient or a negative gradient at an interval of a reference or, alternatively, predetermined control time dt, and may control (i.e., decrease or maintain) a load current based on the gradient of the battery voltage VBATT at an interval of the reference or, alternatively, predetermined control time dt. Here, the reference or, alternatively, predetermined control time dt may be variously

determined according to required conditions for the electronic device. Thus, the reference or, alternatively, predetermined control time dt may be properly adjusted based on a trade-off relation between an accuracy of the battery voltage control operation and the number of times controlling the load current. For example, the reference or, alternatively, predetermined control time dt may be determined to be a settling time of the load current.

Specifically, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the negative gradient at the point A because the battery voltage VBATT decreases toward a level that is lower than the threshold value VTH at the point A. Thus, the method of FIG. **1** may decrease the load current by a reference or, alternatively, predetermined value at the point A. Subsequently, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the negative gradient at the points B and C because a current battery voltage VBATT is smaller than a previous battery voltage VBATT at the points B and C. Thus, the method of FIG. **1** may decrease the load current by the reference or, alternatively, predetermined value at the points B and C. However, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the positive gradient at the point D because the current battery voltage VBATT is greater than the previous battery voltage VBATT at the point D. Thus, the method of FIG. **1** may maintain the load current at the point D. Similarly, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the positive gradient at the point E because the current battery voltage VBATT is greater than the previous battery voltage VBATT at the point E. Thus, the method of FIG. **1** may maintain the load current at the point E.

Generally, a determination that the gradient of the battery voltage VBATT is the positive gradient indicates that the load current is sufficiently reduced. Thus, the battery voltage VBATT is likely to continuously increase. However, as described above, an electronic device includes a plurality of controllable loads of which the load current can be controlled and a plurality of uncontrollable loads of which the load current cannot be controlled. Thus, a phenomenon in which the battery voltage VBATT instantaneously, or within a relatively short period of time, falls into a battery operation-disabled region may occur because the load current flowing through the uncontrollable loads might instantaneously, or within a relatively short period of time, increase although the load current flowing through the controllable loads are sufficiently reduced. For this reason, the method of FIG. **1** may control (i.e., decrease or maintain) the load current based on the gradient of the battery voltage VBATT at an interval of the reference or, alternatively, predetermined control time dt even when the method of FIG. **1** determines that the gradient of the battery voltage VBATT is the positive gradient. For example, even when the gradient of the battery voltage VBATT is the positive gradient at the points D and E, the gradient of the battery voltage VBATT may be the negative gradient at the point F. Thus, the method of FIG. **1** may decrease the load current by the reference or, alternatively, predetermined value at the point F.

Next, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the positive gradient at the points G and H because the current battery voltage VBATT is greater than the previous battery voltage VBATT at the points G and H. Thus, the method of FIG. **1** may continuously maintain the load current. In this situation, the method of FIG. **1** may finish the battery voltage control operation (i.e., indicated as the point I) when the battery voltage VBATT becomes higher than the threshold value VTH. As a result, the monitoring operation on the battery voltage VBATT may be finished. In some example embodiments of the inventive concepts, the method of FIG. **1** may increase the load current during a reference or, alternatively, predetermined additional time when the battery voltage control operation is finished. In this case, the monitoring operation on the battery voltage VBATT may be additionally performed during the reference or, alternatively, predetermined additional time after the battery voltage control operation is finished (i.e., indicated as the point I). As described above, the method of FIG. **1** may prevent an instantaneous, or relatively brief, sharp decrease of the battery voltage VBATT by sensing the gradient of the battery voltage VBATT to decrease or maintain the load current based on the gradient of the battery voltage VBATT when the battery voltage VBATT becomes lower than the reference or, alternatively, predetermined threshold value VTH as the loads of the electronic device instantaneously, or within a relatively short period of time, use the large load current. In addition, the method of FIG. **1** may quickly respond to instantaneous, or relatively brief, current changes because the method of FIG. **1** needs only information related to the gradient of the battery voltage VBATT to control the load current.

FIG. **4** is a diagram illustrating another example in which a load current is controlled by a method of FIG. **1**.

Referring to FIG. **4**, the method of FIG. **1** may begin a battery voltage control operation (i.e., indicated as a point A) when a battery voltage VBATT becomes lower than a first threshold value VTH**1** as a plurality of loads of an electronic device instantaneously, or within a relatively short period of time, use a large load current. In addition, the method of FIG. **1** may finish the battery voltage control operation (i.e., indicated as a point I) when the battery voltage VBATT becomes higher than a second threshold value VTH**2**, where the second threshold value VTH**2** is greater than the first threshold value VTH**1**. As a result, a hysteresis range may exist between the first threshold value VTH**1** for deciding whether or not to begin the battery voltage control operation and the second threshold value VTH**2** for deciding whether or not to finish the battery voltage control operation. That is, it is illustrated in FIG. **3** that the first threshold value VTH**1** is equal to the second threshold value VTH**2**, and it is illustrated in FIG. **4** that the first threshold value VTH**1** is different from the second threshold value VTH**2**. Although it is illustrated in FIG. **4** that the first threshold value VTH**1** is greater than the second threshold value VTH**2**, the present inventive concept is not limited thereto. Thus, in some example embodiments of the inventive concepts, the first threshold value VTH**1** may be greater than the second threshold value VTH**2**. Except that the first threshold value VTH**1** for deciding whether or not to begin the battery voltage control operation is different from the second threshold value VTH**2** for deciding whether or not to finish the battery voltage control operation, the battery voltage control operation of FIG. **3** is the same as the battery voltage control operation of FIG. **4**, and thus the duplicated descriptions will not be repeated.

FIG. **5** is a flow chart illustrating a process in which a gradient of a battery voltage is sensed by a method of FIG. **1**. FIG. **6** is a diagram illustrating an example in which a gradient of a battery voltage is sensed by a method of FIG. **1**.

Referring to FIGS. **5** and **6**, when the method of FIG. **1** performs a battery voltage control operation, the method of FIG. **1** may receive a battery voltage at an (n−1)th time (Step S**220**), and may measure a battery voltage at an (n)th time (Step S**240**), where the (n)th time is the time when a reference or, alternatively, predetermined control time dt elapses after the (n−1)th time. Here, the battery voltage at the (n−1)th time

may be measured in order to control a load current at the (n−1)th time. Subsequently, since the battery voltage at the (n−1)th time and the battery voltage at the (n)th time are acquired, the method of FIG. **1** may determine whether or not the battery voltage at the (n)th time is greater than the battery voltage at the (n−1)th time (Step S**260**) by comparing the battery voltage at the (n)th time with the battery voltage at the (n−1)th time. Here, when the battery voltage at the (n)th time is greater than the battery voltage at the (n−1)th time, the method of FIG. **1** may determine that a gradient of the battery voltage at the (n)th time is a positive gradient PF (Step S**280**). On the other hand, when the battery voltage at the (n−1)th time is greater than the battery voltage at the (n)th time, the method of FIG. **1** may determine that the gradient of the battery voltage at the (n)th time is a negative gradient NF (Step S**290**).

For example, it is assumed that the method of FIG. **1** controls the load current at an interval of the reference or, alternatively, predetermined control time dt when performing the battery voltage control operation. As illustrated in FIG. **6**, a time difference corresponding to the reference or, alternatively, predetermined control time dt exists between adjacent two times (i.e., a first time AT and a second time BT, a second time BT and a third time CT, a third time CT and a fourth time DT). In this case, the gradient of the battery voltage at the second time BT may be determined by comparing the battery voltage at the first time AT with the battery voltage at the second time BT. As a result, since the battery voltage at the first time AT is greater than the battery voltage at the second time BT, the gradient of the battery voltage at the second time BT may be determined to be the negative gradient NF. In addition, the gradient of the battery voltage at the third time CT may be determined by comparing the battery voltage at the second time BT with the battery voltage at the third time CT. As a result, since the battery voltage at the second time BT is greater than the battery voltage at the third time CT, the gradient of the battery voltage at the third time CT may be determined to be the negative gradient NE Further, the gradient of the battery voltage at the fourth time DT may be determined by comparing the battery voltage at the third time CT with the battery voltage at the fourth time DT. As a result, since the battery voltage at the third time CT is smaller than the battery voltage at the fourth time DT, the gradient of the battery voltage at the fourth time DT may be determined to be the positive gradient PF.

FIG. **7** is a flow chart illustrating a process in which a load current is increased one time after a battery voltage control operation is finished by a method of FIG. **1**. FIG. **8** is a diagram illustrating an example in which a load current is increased one time after a battery voltage control operation is finished by a method of FIG. **1**. FIG. **9** is a diagram illustrating another example in which a load current is increased one time after a battery voltage control operation is finished by a method of FIG. **1**.

Referring to FIGS. **7** through **9**, the method of FIG. **1** may finish a battery voltage control operation (Step S**320**), and then may increase a load current flowing through loads by a reference or, alternatively, predetermined value (Step S**340**).

As illustrated in FIG. **8**, the method of FIG. **1** may begin the battery voltage control operation (i.e., indicated as a point A) when the battery voltage VBATT becomes lower than a threshold value VTH as the loads of an electronic device instantaneously, or within a relatively short period of time, use a large load current, and may finish the battery voltage control operation (i.e., indicated as a point I) when the battery voltage VBATT becomes higher than the threshold value VTH as the battery voltage control operation is performed. Here, the method of FIG. **1** may increase the load current flowing through the loads by a reference or, alternatively, predetermined value when the battery voltage control operation is finished (i.e., indicated as the point I). Similarly, as illustrated in FIG. **9**, the method of FIG. **1** may begin the battery voltage control operation (i.e., indicated as a point A) when the battery voltage VBATT becomes lower than a first threshold value VTH**1** as the loads of the electronic device instantaneously, or within a relatively short period of time, use the large load current, and may finish the battery voltage control operation (i.e., indicated as a point I) when the battery voltage VBATT becomes higher than a second threshold value VTH**2** as the battery voltage control operation is performed. As illustrated in FIG. **9**, the second threshold value VTH**2** may be greater than the first threshold value VTH**1**. Here, the method of FIG. **1** may increase the load current flowing through the loads by a reference or, alternatively, predetermined value when the battery voltage control operation is finished (i.e., indicated as the point I). As described above, the method of FIG. **1** may increase the load current flowing through the loads when the battery voltage control operation is finished. Thus, the method of FIG. **1** may quickly restore operations of the loads that are limited by the reduced load current flowing through the loads (i.e., by the battery voltage control operation). Although it is illustrated in FIGS. **7** through **9** that the method of FIG. **1** increases the load current one time after the battery voltage control operation is finished, the number of times increasing the load current is not limited thereto.

FIG. **10** is a flow chart illustrating a process in which a load current is increased one or more times during a reference or, alternatively, predetermined additional time after a battery voltage control operation is finished by a method of FIG. **1**. FIG. **11** is a diagram illustrating an example in which a load current is increased one or more times during a reference or, alternatively, predetermined additional time after a battery voltage control operation is finished by a method of FIG. **1**. FIG. **12** is a diagram illustrating another example in which a load current is increased one or more times during a reference or, alternatively, predetermined additional time after a battery voltage control operation is finished by a method of FIG. **1**.

Referring to FIGS. **10** through **12**, the method of FIG. **1** may finish a battery voltage control operation (Step S**420**), and then may increase or maintain a load current based on a gradient of a battery voltage VBATT (Step S**440**). Here, the method of FIG. **1** may check whether or not a reference or, alternatively, predetermined additional time PDT elapses (Step S**460**), and then may repeat or finish the above process (i.e., Step S**420**, Step S**440**, and Step S**460**) based on the check result. As illustrated in FIGS. **10** through **12**, the method of FIG. **1** may increase or maintain the load current based on the gradient of the battery voltage VBATT after the battery voltage control operation is finished. Thus, a monitoring operation on the battery voltage VBATT may be additionally performed during the reference or, alternatively, predetermined additional time PDT after the battery voltage control operation is finished (i.e., indicated as a point A').

FIG. **11** shows an example in which a first threshold value VTH for deciding whether or not to begin the battery voltage control operation is equal to a second threshold value VTH for deciding whether or not to finish the battery voltage control operation. As illustrated in FIG. **11**, the method of FIG. **1** may finish the battery voltage control operation when the battery voltage VBATT becomes higher than the second threshold value VTH as the battery voltage control operation is performed. In addition, the method of FIG. **1** may increase the load current one or more times during a reference or, alterna-

tively, predetermined additional time PDT by increasing or maintaining the load current based on the gradient of the battery voltage VBATT during the reference or, alternatively, predetermined additional time PDT. In detail, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the positive gradient at a point A' because the battery voltage VBATT becomes (i.e., increases) higher than the second threshold value VTH. Thus, the method of FIG. **1** may increase the load current by a reference or, alternatively, predetermined value at the point 'A'. Subsequently, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the positive gradient at a point B' because the current battery voltage VBATT is greater than the previous battery voltage VBATT. Thus, the method of FIG. **1** may increase the load current by the reference or, alternatively, predetermined value at the point B'. On the other hand, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the negative gradient at a point C' because the current battery voltage VBATT is smaller than the previous battery voltage VBATT. Thus, the method of FIG. **1** may maintain the load current at the point C'. Subsequently, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the positive gradient at a point D' because the current battery voltage VBATT is greater than the previous battery voltage VBATT. Thus, the method of FIG. **1** may increase the load current by the reference or, alternatively, predetermined value at the point D'. However, the method of FIG. **1** may not increase the load current after the reference or, alternatively, predetermined additional time PDT elapses (i.e., from a point E').

FIG. **12** shows an example in which a first threshold value VTH**1** for deciding whether or not to begin the battery voltage control operation is different from a second threshold value VTH**2** for deciding whether or not to finish the battery voltage control operation. As illustrated in FIG. **12**, the method of FIG. **1** may finish the battery voltage control operation when the battery voltage VBATT becomes higher than the second threshold value VTH**2** as the battery voltage control operation is performed. In addition, the method of FIG. **1** may increase the load current one or more times during the reference or, alternatively, predetermined additional time PDT by increasing or maintaining the load current based on the gradient of the battery voltage VBATT during the reference or, alternatively, predetermined additional time PDT. In detail, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the positive gradient at a point N because the battery voltage VBATT becomes (i.e., increases) higher than the second threshold value VTH**2**. Thus, the method of FIG. **1** may increase the load current by the reference or, alternatively, predetermined value at the point 'A'. Subsequently, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the positive gradient at a point B' because the current battery voltage VBATT is greater than the previous battery voltage VBATT. Thus, the method of FIG. **1** may increase the load current by the reference or, alternatively, predetermined value at the point B'. On the other hand, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the negative gradient at a point C' because the current battery voltage VBATT is smaller than the previous battery voltage VBATT. Thus, the method of FIG. **1** may maintain the load current at the point C'. Subsequently, the method of FIG. **1** may determine that the gradient of the battery voltage VBATT is the positive gradient at a point D' because the current battery voltage VBATT is greater than the previous battery voltage VBATT. Thus, the method of FIG. **1** may increase the load current by the reference or, alternatively, predetermined value at the point D'. However, the method of FIG. **1** may not increase the load current after the reference or, alternatively, predetermined additional time PDT elapses (i.e., from a point E').

In conclusion, the method of FIG. **1** may increase or maintain the load current flowing through the loads based on the gradient of the battery voltage VBATT during the reference or, alternatively, predetermined additional time PDT. As illustrated in FIGS. **10** through **12**, the method of FIG. **1** increases the load current one or more times after the battery voltage control operation is finished. As a result, the method of FIG. **1** may quickly restore operations of the loads that are limited by the reduced load current flowing through the loads (i.e., by the battery voltage control operation).

FIG. **13** is a block diagram illustrating a load current control device according to example embodiments of the inventive concepts.

Referring to FIG. **13**, the load current control device **100** may include a voltage comparison unit **120**, a gradient determination unit **140**, a load current control unit **160**, and a timer unit **180**.

The voltage comparison unit **120** may decide whether or not to perform a battery voltage control operation by comparing a battery voltage VBATT with a threshold value VTH. Specifically, the voltage comparison unit **120** may receive the battery voltage VBATT and the threshold value VTH, may compare the battery voltage VBATT with the threshold value VTH, and may output an enabling signal EN for performing the battery voltage control operation, or a disenabling signal DI for finishing the battery voltage control operation to the gradient determination unit **140** based on the comparison result. Here, the voltage comparison unit **120** may provide the enabling signal EN to the gradient determination unit **140** when the battery voltage VBATT becomes lower than the threshold value VTH, and may provide the disenabling signal DI to the gradient determination unit **140** when the battery voltage VBATT becomes higher than the threshold value VTH. Subsequently, the gradient determination unit **140** may perform the battery voltage control operation based on the enabling signal EN, and may finish the battery voltage control operation based on the disenabling signal DI.

When the voltage comparison unit **120** decides to perform the battery voltage control operation, the gradient determination unit **140** may determine whether a gradient of the battery voltage VBATT is a positive gradient or a negative gradient at an interval of a reference or, alternatively, predetermined control time. In one example embodiment, the gradient determination unit **140** may include a first sampler circuit that samples and outputs the battery voltage VBATT at a first time, a second sampler circuit that samples and outputs the battery voltage VBATT at a second time, where the second time is the time when the reference or, alternatively, predetermined control time elapses after the first time, and a comparator circuit that compares the battery voltage VBATT at the first time with the battery voltage VBATT at the second time. The first sampler circuit, the second sampler circuit, and the comparator circuit will be described below with reference to FIG. **14**. Specifically, the gradient determination unit **140** may measure the battery voltage VBATT at the first time, and may measure the battery voltage VBATT at the second time. Next, the gradient determination unit **140** may determine that the gradient of the battery voltage VBATT is the negative gradient when the battery voltage VBATT at the first time is greater than the battery voltage VBATT at the second time, and may determine that the gradient of the battery voltage VBATT is the positive gradient when the battery voltage VBATT at the first time is smaller than the battery voltage VBATT at the second time. Thus, the gradient determination unit **140** may

provide a determination result signal FG to the load current control unit **160**, where the determination result signal FG indicates whether the gradient of the battery voltage VBATT is the positive gradient or the negative gradient.

When the voltage comparison unit **120** decides to perform the battery voltage control operation, the load current control unit **160** may control (i.e., decrease or maintain) the load current flowing through the loads based on the gradient of the battery voltage VBATT at an interval of the reference or, alternatively, predetermined control time. Specifically, the load current control unit **160** may receive the determination result signal FG from the gradient determination unit **140**, where the determination result signal FG indicates whether the gradient of the battery voltage VBATT is the positive gradient or the negative gradient. Subsequently, the load current control unit **160** may decrease the load current flowing through the loads when the determination result signal FG indicates that the gradient of the battery voltage VBATT is the negative gradient, and may maintain the load current flowing through the loads when the determination result signal FG indicates that the gradient of the battery voltage VBATT is the positive gradient. Thus, the load current control unit **160** may output a control signal SCTL to maintain the load current flowing through the loads, or to decrease the load current flowing through the loads. In some example embodiments of the inventive concepts, the load current control unit **160** may increase the load current flowing through the loads when the battery voltage control operation is finished. For example, the load current control unit **160** may increase the load current flowing through the loads one time after the battery voltage control operation is finished, or may increase the load current flowing through the loads one or more times during a reference or, alternatively, predetermined additional time after the battery voltage control operation is finished. Since these are described above, the duplicated descriptions will not be repeated.

When the voltage comparison unit **120** decides to perform the battery voltage control operation, the timer unit **180** may provide time information TI to the gradient determination unit **140** at an interval of the reference or, alternatively, predetermined control time. Thus, at an interval of the reference or, alternatively, predetermined control time, the gradient determination unit **140** may determine whether the gradient of the battery voltage VBATT is the positive gradient or the negative gradient by using the time information TI. Accordingly, at an interval of the reference or, alternatively, predetermined control time, the load current control unit **160** may control (i.e., decrease or maintain) the load current flowing through the loads based on the gradient of the battery voltage VBATT. As described above, the load current control device **100** may include the voltage comparison unit **120**, the gradient determination unit **140**, the load current control unit **160**, and the timer unit **180**. On this basis, the load current control device **100** may prevent an instantaneous, or relatively brief, sharp decrease of the battery voltage VBATT by sensing the gradient of the battery voltage VBATT to control (i.e., decrease or maintain) the load current based on the gradient of the battery voltage VBATT when the battery voltage VBATT becomes (i.e., decreases) lower than the reference or, alternatively, predetermined threshold value VTH as the loads instantaneously, or within a relatively short period of time, use a large load current. In addition, the load current control device **100** may quickly respond to instantaneous, or relatively brief, current changes because the load current control device **100** needs only information related to the gradient of the battery voltage VBATT to control the load current flowing through the loads.

FIG. **14** is a block diagram illustrating a gradient determination unit included in a load current control device of FIG. **13**.

Referring to FIG. **14**, the gradient determination unit **140** may include a first sampler circuit **142-1**, a second sampler circuit **142-2**, and a comparator circuit **144**.

The first sampler circuit **142-1** may sample a battery voltage VBATT at an (n−1)th time, and may output the battery voltage V(n−1) at the (n−1)th time to a first input terminal of the comparator circuit **144**. The second sampler circuit **142-2** may sample a battery voltage VBATT at an (n)th time, and may output the battery voltage V(n) at the (n)th time to a second input terminal of the comparator circuit **144**. Here, the (n)th time is the time when a reference or, alternatively, predetermined control time elapses after the (n−1)th time. Although it is illustrated in FIG. **14** that the first input terminal corresponds to a negative input terminal and the second input terminal corresponds to a positive input terminal, a structure of the gradient determination unit **140** is not limited thereto. For example, the first input terminal may correspond to the positive input terminal, and the second input terminal may correspond to the negative input terminal. The comparator circuit **144** may receive the battery voltage V(n−1) at the (n−1)th time and the battery voltage V(n) at the (n)th time, and may compare the battery voltage V(n−1) at the (n−1)th time with the battery voltage V(n) at the (n)th time. Based on the comparison result, the comparator circuit **144** may output a determination result signal FG indicating whether a gradient of the battery voltage VBATT is a positive gradient or a negative gradient. Here, the gradient determination unit **140** may determine that the gradient of the battery voltage VBATT is the negative gradient when the battery voltage V(n−1) at the (n−1)th time is greater than the battery voltage V(n) at the (n)th time, and may determine that the gradient of the battery voltage VBATT is the positive gradient when the battery voltage V(n−1) at the (n−1)th time is smaller than the battery voltage V(n) at the (n)th time.

FIG. **15** is a block diagram illustrating a battery voltage control operation that is performed by a load current control device of FIG. **13**. FIG. **16** is a concept diagram illustrating a battery voltage control operation that is performed by a load current control device of FIG. **13**.

Referring to FIGS. **15** and **16**, the electronic device **300** that operates based on a battery **320** may include a battery **320**, a charger **330**, controllable loads **340**, and uncontrollable loads **350**. Here, the battery **320** may provide a battery voltage to the controllable loads **340** and the uncontrollable loads **350** using the charger **330**. The charger **330** may perform a charging operation on the battery **320**, or may deliver the battery voltage to the controllable loads **340** and the uncontrollable loads **350**. As described above, the controllable loads **340** indicate loads of which a load current can be controlled by the electronic device **300**. For example, the controllable loads **340** may include an LED driver, an internal function module, etc. On the other hand, the uncontrollable loads **350** indicate loads of which a load current cannot be controlled by the electronic device **300**. For example, the uncontrollable loads **350** may include an external function module, etc. When the controllable loads **340** and the uncontrollable loads **350** instantaneously, or within a relatively short period of time, use a large load current, the battery voltage may instantaneously, or within a relatively short period of time, fall into a battery operation-disabled region although an actual battery voltage is in a battery operation-enabled region. As a result, the electronic device **300** may malfunction, or may stop performing various functions.

However, the load current control device **100** may prevent an instantaneous, or relatively brief, sharp decrease of the battery voltage when the controllable loads **340** and the uncontrollable loads **350** instantaneously, or within a relatively short period of time, use the large load current in the electronic device **300**. For this operation, as illustrated in FIG. **16**, the load current control device **100** may operate in either a battery voltage controllable mode **420** or a battery voltage uncontrollable mode **440**. Specifically, the load current control device **100** may perform a battery voltage control operation when the battery voltage becomes (i.e., decreases) lower than a reference or, alternatively, predetermined threshold value VTH as the controllable loads **340** and the uncontrollable loads **350** instantaneously, or within a relatively short period of time, use the large load current in the electronic device **300**. In other words, the load current control device **100** may operate in the battery voltage controllable mode **420**. On the other hand, the load current control device **100** may finish the battery voltage control operation when the battery voltage becomes (i.e., increases) higher than the reference or, alternatively, predetermined threshold value VTH. In other words, the load current control device **100** may operate in the battery voltage uncontrollable mode **440**.

As described above, the load current control device **100** may decide whether or not to perform the battery voltage control operation based on the reference or, alternatively, predetermined threshold value VTH. In one example embodiment, the threshold value VTH for deciding whether or not to begin the battery voltage control operation may be equal to the threshold value VTH for deciding whether or not to finish the battery voltage control operation. In another example embodiment, the threshold value VTH for deciding whether or not to begin the battery voltage control operation may be different from the threshold value VTH for deciding whether or not to finish the battery voltage control operation. In this way, the load current control device **100** may prevent an instantaneous, or relatively brief, sharp decrease of the battery voltage by sensing the gradient of the battery voltage to control (i.e., decrease or maintain) the load current based on the gradient of the battery voltage when the battery voltage becomes lower than the threshold value VTH. In addition, the load current control device **100** may quickly respond to instantaneous, or relatively brief, current changes because the load current control device **100** needs only information related to the gradient of the battery voltage to control the load current. Meanwhile, it should be understood that the load current control device **100** indirectly controls the load current used by the uncontrollable loads **350** by controlling the load current used by the controllable loads **340** as well as the load current control device **100** directly controls the load current used by the controllable loads **340**.

FIG. **17** is a block diagram illustrating a load current control device according to example embodiments of the inventive concepts.

Referring to FIG. **17**, the load current control device **200** may include a voltage comparison unit **220**, a gradient determination unit **240**, a load current control unit **260**, and a timer unit **280**.

The voltage comparison unit **220** may decide whether or not to perform a battery voltage control operation by comparing a battery voltage VBATT with a first threshold value VTH**1** for deciding whether or not to begin the battery voltage control operation and a second threshold value VTH**2** for deciding whether or not to finish the battery voltage control operation. In one example embodiment, the first threshold value VTH**1** may be different from the second threshold value VTH**2**. In another example embodiment, the first threshold value VTH**1** may be equal to the second threshold value VTH**2**. However, the present inventive concept is not limited thereto. In case that the first threshold value VTH**1** is different from the second threshold value VTH**2**, a hysteresis range may exist between the first threshold value VTH**1** for deciding whether or not to begin the battery voltage control operation and the second threshold value VTH**2** for deciding whether or not to finish the battery voltage control operation. Specifically, the voltage comparison unit **220** may receive the battery voltage VBATT, the first threshold value VTH**1**, and the second threshold value VTH**2**, may compare the battery voltage VBATT with the first threshold value VTH**1** and the second threshold value VTH**2**, and may output an enabling signal EN for performing the battery voltage control operation, or a disenabling signal DI for finishing the battery voltage control operation to the gradient determination unit **240** based on the comparison result. Here, the voltage comparison unit **220** may provide the enabling signal EN to the gradient determination unit **240** when the battery voltage VBATT becomes lower than the first threshold value VTH**1**, and may provide the disenabling signal DI to the gradient determination unit **240** when the battery voltage VBATT becomes higher than the second threshold value VTH**2**. Subsequently, the gradient determination unit **240** may perform the battery voltage control operation based on the enabling signal EN, and may finish the battery voltage control operation based on the disenabling signal DI.

When the voltage comparison unit **220** decides to perform the battery voltage control operation, the gradient determination unit **240** may determine whether a gradient of the battery voltage VBATT is a positive gradient or a negative gradient at an interval of a reference or, alternatively, predetermined control time. In one example embodiment, the gradient determination unit **240** may include a first sampler circuit that samples and outputs the battery voltage VBATT at a first time, a second sampler circuit that samples and outputs the battery voltage VBATT at a second time, where the second time is the time when the reference or, alternatively, predetermined control time elapses after the first time, and a comparator circuit that compares the battery voltage VBATT at the first time with the battery voltage VBATT at the second time. Specifically, the gradient determination unit **240** may measure the battery voltage VBATT at the first time, and may measure the battery voltage VBATT at the second time. Next, the gradient determination unit **240** may determine that the gradient of the battery voltage VBATT is the negative gradient when the battery voltage VBATT at the first time is greater than the battery voltage VBATT at the second time, and may determine that the gradient of the battery voltage VBATT is the positive gradient when the battery voltage VBATT at the first time is smaller than the battery voltage VBATT at the second time. Thus, the gradient determination unit **240** may provide a determination result signal FG to the load current control unit **260**, where the determination result signal FG indicates whether the gradient of the battery voltage VBATT is the positive gradient or the negative gradient.

When the voltage comparison unit **220** decides to perform the battery voltage control operation, the load current control unit **260** may control (i.e., decrease or maintain) the load current flowing through the loads based on the gradient of the battery voltage VBATT at an interval of the reference or, alternatively, predetermined control time. Specifically, the load current control unit **260** may receive the determination result signal FG from the gradient determination unit **240**, where the determination result signal FG indicates whether the gradient of the battery voltage VBATT is the positive gradient or the negative gradient. Subsequently, the load cur-

rent control unit **260** may decrease the load current flowing through the loads when the determination result signal FG indicates that the gradient of the battery voltage VBATT is the negative gradient, and may maintain the load current flowing through the loads when the determination result signal FG indicates that the gradient of the battery voltage VBATT is the positive gradient. Thus, the load current control unit **260** may output a control signal SCTL to maintain the load current flowing through the loads, or to decrease the load current flowing through the loads. In some example embodiments of the inventive concepts, the load current control unit **260** may increase the load current flowing through the loads when the battery voltage control operation is finished. For example, the load current control unit **260** may increase the load current flowing through the loads one time after the battery voltage control operation is finished, or may increase the load current flowing through the loads one or more times during a reference or, alternatively, predetermined additional time after the battery voltage control operation is finished. Since these are described above, the duplicated descriptions will not be repeated.

When the voltage comparison unit **220** decides to perform the battery voltage control operation, the timer unit **280** may provide time information TI to the gradient determination unit **240** at an interval of the reference or, alternatively, predetermined control time. Thus, at an interval of the reference or, alternatively, predetermined control time, the gradient determination unit **240** may determine whether the gradient of the battery voltage VBATT is the positive gradient or the negative gradient by using the time information TI. Accordingly, at an interval of the reference or, alternatively, predetermined control time, the load current control unit **260** may control (i.e., decrease or maintain) the load current flowing through the loads based on the gradient of the battery voltage VBATT. As described above, the load current control device **200** may include the voltage comparison unit **220**, the gradient determination unit **240**, the load current control unit **260**, and the timer unit **280**. On this basis, the load current control device **200** may prevent an instantaneous, or relatively brief, sharp decrease of the battery voltage VBATT by sensing the gradient of the battery voltage VBATT to control (i.e., decrease or maintain) the load current based on the gradient of the battery voltage VBATT when the battery voltage VBATT becomes (i.e., decreases) lower than a reference or, alternatively, predetermined threshold value (i.e., the first threshold value VTH**1**) as the loads instantaneously, or within a relatively short period of time, use a large load current. In addition, the load current control device **200** may quickly respond to instantaneous, or relatively brief, current changes because the load current control device **200** needs only information related to the gradient of the battery voltage VBATT to control the load current flowing through the loads.

FIG. **18** is a block diagram illustrating a mobile device having a load current control device according to example embodiments of the inventive concepts. FIG. **19** is a block diagram illustrating an example in which a mobile device of FIG. **18** is implemented as a smart-phone.

Referring to FIGS. **18** and **19**, the mobile device **500** may include an application processor (AP) **510**, a memory device **520**, a storage device **530**, function modules **540**, **550**, **560**, and **570**, and a power module **580** that provides an internal voltage to the application processor **510**, the memory device **520**, the storage device **530**, and the function modules **540**, **550**, **560** and **570**, respectively. Here, the power module **580** may include a load current control device that controls a load current based on a gradient of a battery voltage when performing a battery voltage control operation. As illustrated in FIG. **19**, the mobile device **500** may be implemented as a smart-phone.

The application processor **510** may control overall operations of the mobile device **500**. That is, the application processor **510** may control the memory device **520**, the storage device **530**, and the function modules **540**, **550**, **560**, and **570**. The memory device **520** and the storage device **530** may store data for operations of the mobile device **500**. For example, the memory device **520** may correspond to a volatile semiconductor memory device such as a dynamic random access memory (DRAM) device, a static random access memory (SRAM) device, a mobile DRAM, etc. In addition, the storage device **530** may correspond to a non-volatile semiconductor memory device such as an erasable programmable read-only memory (EPROM) device, an electrically erasable programmable read-only memory (EEPROM) device, a flash memory device, a phase change random access memory (PRAM) device, a resistance random access memory (RRAM) device, a nano floating gate memory (NFGM) device, a polymer random access memory (PoRAM) device, a magnetic random access memory (MRAM) device, a ferroelectric random access memory (FRAM) device, etc. In some example embodiments of the inventive concepts, the storage device **530** may correspond to a solid state drive (SSD) device, a hard disk drive (HDD) device, a CD-ROM device, etc.

The function modules **540**, **550**, **560**, and **570** may perform various functions of the mobile device **500**. For example, the mobile device **500** may include a communication module **540** that performs a communication function (e.g., a code division multiple access (CDMA) module, a long term evolution (LTE) module, a radio frequency (RF) module, an ultra wideband (UWB) module, a wireless local area network (WLAN) module, a worldwide interoperability for microwave access (WIMAX) module, etc), a camera module **550** that performs a camera function, a display module **560** that performs a display function, a touch panel module **570** that performs a touch sensing function, etc. In some example embodiments of the inventive concepts, the mobile device **500** may further include a global positioning system (GPS) module, a microphone (MIC) module, a speaker module, a gyroscope module, etc. However, a kind of the function modules **540**, **550**, **560**, and **570** included in the mobile device **500** is not limited thereto. Meanwhile, the memory device **520**, the storage device **530**, and the function modules **540**, **550**, **560**, and **570** may be classified into controllable loads and uncontrollable loads according to operational characteristics thereof.

The power module **580** may provide the battery voltage to the application processor **510**, the memory device **520**, the storage device **530**, and the function modules **540**, **550**, **560**, and **570**. Here, the power module **580** may include the battery **582** that supplies the battery voltage and the load current control device **584** that controls the load current based on the gradient of the battery voltage when performing the battery voltage control operation. In one example embodiment, the load current control device **584** may include a voltage comparison unit that decides whether or not to perform the battery voltage control operation by comparing the battery voltage with a threshold value, a gradient determination unit that determines whether the gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation, a load current control unit that controls the load current based on the gradient of the battery voltage at an interval of the reference or, alternatively, prede-

termined control time when the voltage comparison unit decides to perform the battery voltage control operation, and a timer unit that provides time information to the gradient determination unit at an interval of the reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation. For example, according to example embodiments of the inventive concepts, the load current control device **584** may include the structure and operation of the load current control device **100** described above with reference to FIG. **13**. In another example embodiment, the load current control device **584** may include a voltage comparison unit that decides whether or not to perform the battery voltage control operation by comparing the battery voltage with a first threshold value and a second threshold value, where the first threshold value is different from the second threshold value, a gradient determination unit that determines whether the gradient of the battery voltage is the positive gradient or the negative gradient at an interval of the reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation, a load current control unit that controls the load current based on the gradient of the battery voltage at an interval of the reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation, and a timer unit that provides the time information to the gradient determination unit at an interval of the reference or, alternatively, predetermined control time when the voltage comparison unit decides to perform the battery voltage control operation. For example, according to example embodiments of the inventive concepts, the load current control device **584** may include the structure and operation of the load current control device **200** described above with reference to FIG. **17**.

As described above, the load current control device **584** may perform the battery voltage control operation when the battery voltage becomes lower than the threshold value (or, the first threshold value), and may finish the battery voltage control operation when the battery voltage becomes higher than the threshold value (or, the second threshold value). In addition, at an interval of the reference or, alternatively, predetermined control time, the load current control device **584** may decrease the load current flowing through the loads by a reference or, alternatively, predetermined value when determining that the gradient of the battery voltage is the negative gradient, and may maintain the load current flowing through the loads when determining that the gradient of the battery voltage is the positive gradient. To determine whether the gradient of the battery voltage is the positive gradient or the negative gradient, the load current control device **584** may compare the battery voltage at a first time with the battery voltage at a second time, where the first time is the time when the reference or, alternatively, predetermined control time elapses after the first time. Here, the load current control device **584** may determine that the gradient of the battery voltage is the negative gradient if the battery voltage at the first time is greater than the battery voltage at the second time, and may determine that the gradient of the battery voltage is the positive gradient if the battery voltage at the first time is smaller than the battery voltage at the second time. Further, in some example embodiments of the inventive concepts, the load current control device **584** may increase the load current flowing through the loads when the load current control device **584** finishes the battery voltage control operation. In conclusion, the mobile device **500** may prevent an instantaneous, or relatively brief, sharp decrease of the battery voltage by using the load current control device **584** when the loads of the mobile device **500** instantaneously, or within a relatively short period of time, use the large load current. As a result, the mobile device **500** may achieve a high operational stability (or, reliability).

FIG. **20** is a block diagram illustrating an electronic device having a load current control device according to example embodiments of the inventive concepts.

Referring to FIG. **20**, the electronic device **1000** may include a processor **1010**, a memory device **1020**, a storage device **1030**, a display device **1040**, an input/output (I/O) device **1050**, and a power supply **1060**. In addition, the electronic device **1000** may further include a plurality of ports for communicating a video card, a sound card, a memory card, a universal serial bus (USB) device, other electronic devices, etc.

The processor **1010** may perform various computing functions. The processor **1010** may be a micro-processor, a central processing unit (CPU), etc. The processor **1010** may be coupled to other components (e.g., the memory device **1020**, the storage device **1030**, the display device **1040**, the I/O device **1050**, etc) via an address bus, a control bus, a data bus, etc. In some example embodiments of the inventive concepts, the processor **1010** may be coupled to an extended bus such as a peripheral component interconnection (PCI) bus. The memory device **1020** and the storage device **1030** may store data for operations of the electronic device **1000**. For example, the memory device **1020** may correspond to a volatile semiconductor memory device such as a DRAM device, an SRAM device, a mobile DRAM, etc, and the storage device **1030** may correspond to a non-volatile semiconductor memory device such as an EPROM device, an EEPROM device, a flash memory device, a PRAM device, a RRAM device, an NFGM device, a PoRAM device, an MRAM device, an FRAM device, etc. In some example embodiments of the inventive concepts, the storage device **1030** may correspond to an SSD device, an HDD device, a CD-ROM device, etc.

The display device **1040** may display an image related to data used (or, processed) by the electronic device **1000**. For example, the display device **1040** may be a liquid crystal display (LCD) device, an organic light emitting display (OLED) device, etc. The I/O device **1050** may include an input device such as a keyboard, a keypad, a touch-pad, a touch-screen, a mouse, etc, and an output device such as a speaker, a printer, etc. In some example embodiments of the inventive concepts, the display device **1040** may be included in the I/O device **1050**. The power supply **1060** may provide a power for operations of the electronic device **1000**. Here, the power supply **1060** may include a battery that supplies a battery voltage and a load current control device that controls a load current based on a gradient of the battery voltage when performing a battery voltage control operation. For example, according to example embodiments of the inventive concepts, the power supply **1060** may include the structure and operation of one of the load current control device **100** described above with reference to FIG. **13** and the load current control device **200** described above with reference to FIG. **17**. As described above, the load current control device may prevent an instantaneous, or relatively brief, sharp decrease of the battery voltage by sensing the gradient of the battery voltage to control (i.e., decrease or maintain) the load current based on the gradient of the battery voltage when the battery voltage becomes lower than a reference or, alternatively, predetermined threshold value as a plurality of loads of the electronic device **1000** instantaneously, or within a relatively short period of time, use a large load current. As a result, the

electronic device **1000** may achieve a high operational stability by using the load current control device.

The present inventive concept may be applied to a system that operates based on a battery. For example, the present inventive concept may be applied to a computer, a laptop, a digital camera, a cellular phone, a smart-phone, a smart-pad, a personal digital assistants (PDA), a portable multimedia player (PMP), an MP3 player, a navigation system, a camcorder, an electronic control unit (ECU) for vehicles, a portable game console.

The foregoing is illustrative of example embodiments of the inventive concepts and is not to be construed as limiting thereof. Although a few example embodiments of the inventive concepts have been described, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments of the inventive concepts without materially departing from the novel teachings and advantages of the present inventive concept. Accordingly, all such modifications are intended to be included within the scope of the present inventive concept as defined in the claims. Therefore, it is to be understood that the foregoing is illustrative of various example embodiments of the inventive concepts and is not to be construed as limited to the specific example embodiments of the inventive concepts disclosed, and that modifications to the disclosed example embodiments of the inventive concepts, as well as other example embodiments of the inventive concepts, are intended to be included within the scope of the appended claims.

What is claimed is:

1. A method of controlling a load current, the method comprising:

beginning a battery voltage control operation when a battery voltage becomes lower than a first threshold value, the battery voltage control operation including iteratively,

determining whether a gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference control time, and

controlling the load current based on the gradient of the battery voltage at an interval of the reference control time; and

finishing the battery voltage control operation by ending the determining and the controlling when the battery voltage becomes higher than a second threshold value.

2. The method of claim **1**, wherein the first threshold value is equal to the second threshold value.

3. The method of claim **1**, wherein the first threshold value is different from the second threshold value.

4. The method of claim **1**, wherein determining whether a gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference control time comprises:

measuring the battery voltage at a first time;

measuring the battery voltage at a second time, the first time being earlier than the second time by an amount of time equal to the reference control time;

determining that the gradient of the battery voltage is the negative gradient when the battery voltage at the first time is greater than the battery voltage at the second time; and

determining that the gradient of the battery voltage is the positive gradient when the battery voltage at the first time is smaller than the battery voltage at the second time.

5. The method of claim **4**, wherein controlling the load current based on the gradient of the battery voltage at an interval of the reference control time comprises:

decreasing the load current when the gradient of the battery voltage is determined to be the negative gradient; and

maintaining the load current when the gradient of the battery voltage is determined to be the positive gradient.

6. The method of claim **1**, further comprising:

increasing the load current after the battery voltage control operation is finished.

7. The method of claim **6**, wherein the load current is increased one time after the battery voltage control operation is finished.

8. The method of claim **6**, wherein the load current is increased one or more times during a reference period of time after the battery voltage control operation is finished.

9. A load current control device comprising:

a memory storing computer-readable instructions;

one or more processors configured to execute the instructions to,

decide whether or not to perform a battery voltage control operation by comparing a battery voltage with a threshold value;

when the one or more processors decide to perform the battery voltage control operation, the processor performs the battery voltage control operation by iteratively,

determining whether a gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference control time,

controlling a load current based on the gradient of the battery voltage at an interval of the reference control time, and

providing time information at an interval of the reference control time; and

end the battery voltage control operation by ending the determining and the controlling based on the battery voltage and the threshold value.

10. The device of claim **9**, wherein the one or more processors are configured to decide to perform the battery voltage control operation when the battery voltage becomes lower than the threshold value, and

wherein the one or more processors are configured to end the battery voltage control operation when the battery voltage becomes higher than the threshold value.

11. The device of claim **10**, wherein the one or more processors are configured to measure the battery voltage at a first time, measures the battery voltage at a second time, the second time being the time when the reference control time elapses after the first time, and compares the battery voltage at the first time with the battery voltage at the second time, and

wherein one or more processors are configured to determine that the gradient of the battery voltage is the negative gradient when the battery voltage at the first time is greater than the battery voltage at the second time, and configured to determine that the gradient of the battery voltage is the positive gradient when the battery voltage at the first time is smaller than the battery voltage at the second time.

12. The device of claim **11**, wherein the one or more processors are configured to decrease the load current when the gradient of the battery voltage is determined to be the negative gradient, and configured to maintain the load current when the gradient of the battery voltage is determined to be the positive gradient.

13. The device of claim **12**, wherein the one or more processors are configured to increase the load current after the battery voltage control operation is finished.

14. A load current control device comprising:

a memory storing computer-readable instructions;

one or more processors configured to execute the instructions to,

decide whether or not to perform a battery voltage control operation by comparing a battery voltage with a first threshold value and a second threshold value, the first threshold value being different from the second threshold value,

when the one or more processors decide to perform the battery voltage control operation, the processor performs the battery voltage control operation by iteratively,

determining whether a gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference control time,

controlling a load current based on the gradient of the battery voltage at an interval of the reference control time, and

providing time information at an interval of the reference control time, and

end the battery voltage control operation by ending the determining and the controlling based on the battery voltage and at least one of the first or second threshold.

15. The device of claim **14**, wherein the one or more processors are configured to perform the battery voltage control operation when the battery voltage becomes lower than the first threshold value, and

wherein the one or more processors are configured to end the battery voltage control operation when the battery voltage becomes higher than the second threshold value.

16. The device of claim **15**, wherein the one or more processors are configured to measure the battery voltage at a first time, measure the battery voltage at a second time, the first time being earlier than the second time by an amount of time equal to the reference control time, and compare the battery voltage measured at the first time with the battery voltage measured at the second time, and

wherein the one or more processors are configured to determine that the gradient of the battery voltage is the negative gradient when the battery voltage at the first time is greater than the battery voltage at the second time, and configured to determine that the gradient of the battery voltage is the positive gradient when the battery voltage at the first time is smaller than the battery voltage at the second time.

17. The device of claim **16**, wherein the one or more processors are configured to decrease the load current when the gradient of the battery voltage is determined to be the negative gradient, and configured to maintain the load current when the gradient of the battery voltage is determined to be the positive gradient.

18. The device of claim **17**, wherein the one or more processors are configured to increase the load current after the battery voltage control operation is finished.

19. A mobile device comprising:

an application processor;

at least one memory device;

at least one storage device;

at least one function module; and

a power supply including a battery configured to supply the battery voltage, the power supply being configured to,

provide a battery voltage to the application processor, the memory device, the storage device, and the function module,

begin a battery voltage control operation in response to the battery voltage becoming lower than a first threshold value, the battery voltage control operation including iteratively,

determining whether a gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference control time, and

controlling the load current based on the gradient of the battery voltage at an interval of the reference control time, and

finish the battery voltage control operation by ending the determining and the controlling in response to the battery voltage becoming higher than a second threshold value.

20. The device of claim **19**, wherein the power supply is configured such that the first and second threshold values are the same.

21. The device of claim **19**, wherein the power supply is configured such that the first and second threshold values are different from each other, becomes higher than a second threshold value, the first threshold value being different from the second threshold value.

22. The device of claim **19**, wherein at an interval of a reference control time, power supply is configured to decrease the load current by a reference value when the gradient of the battery voltage is determined to be a negative gradient, and configured to maintain the load current when the gradient of the battery voltage is determined to be a positive gradient.

23. The device of claim **22**, wherein the power supply is configured to determine whether the gradient of the battery voltage is the positive gradient or the negative gradient by comparing the battery voltage at a first time with the battery voltage at a second time, the first time being earlier than the second time by an amount of time equal to the reference control time.

24. The device of claim **19**, wherein the power supply is configured to increase the load current after the battery voltage control operation is finished.

25. A method of controlling a load current of a device including a battery, the method comprising:

choosing, as a load current control mode of the device, one of a first load current control mode and a second load current control mode based on a battery voltage of the battery;

determining whether a gradient of the battery voltage is positive or negative; and

controlling the load current based on the chosen load current control mode of the device and the determined gradient of the battery voltage,

the choosing one of a first load current mode and a second load current mode including,

choosing the first load current control mode as the load current control mode of the device if the battery voltage falls below a first threshold, and

choosing the second load current control mode as the load current control mode of the device if the determined battery voltage rises above a second threshold,

wherein controlling the load current based on the chosen load current control mode of the device and the determined gradient of the battery voltage includes,

if the chosen currently load current control mode of the device is the first load current control mode,

maintaining the current load of the device if the gradient of the battery voltage is a positive, and

decreasing the current load of the device if the gradient of the battery voltage is negative; and

if the chosen currently load current control mode of the device is the second load current control mode,

maintaining the current load of the device if the gradient of the battery voltage is a negative, and

increasing the current load of the device if the gradient of the battery voltage is positive.

26. The method of claim **25**, wherein the first threshold and the second threshold are the same.

27. The method of claim **25**, wherein the first threshold and the second threshold are different.

28. A method of controlling a load current, the method comprising:

beginning a battery voltage control operation when a battery voltage becomes lower than a first threshold value, the battery voltage control operation;

determining whether a gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference control time;

controlling the load current based on the gradient of the battery voltage at an interval of the reference control time; and

finishing the battery voltage control operation by ending the determining and the controlling when the battery voltage becomes higher than a second threshold value,

wherein controlling the load current based on the gradient of the battery voltage at an interval of the reference control time includes,

decreasing the load current when the gradient of the battery voltage is determined to be the negative gradient; and

maintaining the load current when the gradient of the battery voltage is determined to be the positive gradient.

29. The method of claim **28**, wherein the first threshold value is equal to the second threshold value.

30. The method of claim **28**, wherein the first threshold value is different from the second threshold value.

31. A load current control device comprising:

a memory storing computer-readable instructions;

one or more processors configured to execute the instructions to,

begin a battery voltage control operation when a battery voltage becomes lower than a first threshold value, the battery voltage control operation,

determine whether a gradient of the battery voltage is a positive gradient or a negative gradient at an interval of a reference control time;

control the load current based on the gradient of the battery voltage at an interval of the reference control time, and

finish the battery voltage control operation by ending the determining and the controlling when the battery voltage becomes higher than a second threshold value,

wherein the one or more processors are configured such that controlling the load current based on the gradient of the battery voltage at an interval of the reference control time includes,

decreasing the load current when the gradient of the battery voltage is determined to be the negative gradient; and

maintaining the load current when the gradient of the battery voltage is determined to be the positive gradient.

32. The device of claim **31**, wherein the first threshold value is equal to the second threshold value.

33. The device of claim **31**, wherein the first threshold value is different from the second threshold value.

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